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Unequal participation in mathematics and science education

Annemarie van Langen

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UNEQUAL PARTICIPATION IN MATHEMATICS AND SCIENCE EDUCATION

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door

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Contents

Preface

In this book, a series of national and international studies is reported on with the shortage of participation in upper secondary mathematics and science subjects and higher Science, Technology, Engineering and Mathematics (STEM) fields of study by particular groups of pupils – including girls and the children of lower educated parents – as a common underlying theme. Viewed from the perspective of society, such a shortage can be seen to constitute an undesirable phenomenon because it lays the foundation for further inequality in the chances of a favourable position for follow-up education and the employment market. Such inequality is also economically undesirable as a shortage of STEM-educated personnel already exists and a considerable portion of the potential personnel simply excludes itself from STEM employment via its choice of secondary subjects and tertiary fields of study. The results of the research reported on here show a clear relation to continue to exist between the background characteristics of pupils and the extent to which they choose maths and science subjects and STEM fields of study. The relation is nevertheless not the same for all of the schools and countries examined, which provides an opening for improvement as well.

In the conduct of the present research and the writing of this report, I have had the help of many people. I would like to thank a number of them in particular here. To start with, I would like to thank my supervisors, Hetty Dekkers and Roel Bosker, for their inspiring guidance. In addition, Lyset Rekers-Mombarg was of considerable importance for the conduct of many statistical analyses. Numerous ITS colleagues provided assistance: Some – such as Hermann Vierke, Hans Versteegen and Madeleine Hulsen – with the actual conduct of parts of the projects; others – such as Lia Mulder and Geert Driessen – with their commentary on the texts and advice on how to tackle certain matters. Of no less importance, of course, are the people who provided and still provide support for me privately although they are not named here specifically.

The well-known "Choose Exact" campaign was initiated by the Dutch government in 1987. Since then, the theme has never disappeared from the national agenda. This shows just how tough and recalcitrant the topic of this thesis can be. And while the last word has certainly not been said with regard to this topic, I nevertheless hope to have made a modest contribution to the ongoing discussion.

Nijmegen, September 2005
Annemarie van Langen

1 Introduction and theoretical background

1.1 Introduction

This thesis concerns the shortage of participation by certain groups of pupils in secondary mathematics and science education and tertiary Science, Technology, Engineering and Mathematics (STEM) studies. About half way through the 1980s in the Netherlands, the government organized a campaign to motivate more pupils to choose maths and science subjects, but the issue is still current and high on the political agenda. The current perspective is nevertheless somewhat different. In the 1980s, the emphasis was primarily on the lack of an interest among girls and women in maths and science subjects/courses with the continued existence of the presumably undesired segregation of educational and employment opportunities according to gender as a result. At this point, the impending shortage of higher educated STEM personnel and the economic consequences of such a shortage stand central. Viewed from this perspective, the underrepresentation of women is still relevant because an increase in the participation of women to the level of men would basically solve the problem. For similar reasons, the possible underrepresentation of other social-demographic groups including ethnic minorities is also receiving more attention now.

Concern about the shortage of STEM personnel is not limited to the Netherlands. In Lisbon in 2000, the European secretaries of state set a 15% increase in the graduation of individuals from tertiary STEM courses in the EU in 2010 as a major objective for the establishment of Europe as one of the best knowledge economies in the world (European Commission, 2002)[1]. But also outside Europe, for instance in the USA, the promotion of participation in secondary and tertiary STEM education is a recurring theme for research and policy.

This chapter begins with a state-of-the-art overview of pupil participation in secondary maths and science education and tertiary STEM courses. Thereafter, the theoretical framework within which the studies in this thesis were conducted will be presented. And, finally, the specific research questions will be introduced.

1.2 Current participation figures

1.2.1 Maths and science subject choice in the upper levels of Dutch secondary education

Dutch secondary education, today, begins with a two year basic curriculum. Thereafter, the pupils progress to one of three levels: VMBO (*voorbereidend middelbaar beroepsonderwijs*; pre-vocational secondary education), HAVO (*hoger algemeen voortgezet onderwijs*; senior general secondary education) or VWO (*voorbereidend wetenschappelijk onderwijs*; pre-university secondary education). While the latter two levels both prepare pupils for higher levels of education, VWO is already higher than HAVO and the only level which provides direct access to a university degree course. Including the two year basic curriculum, the HAVO takes five years and the VWO six years. Each of the upper levels of secondary education is followed by about 20% of the population of secondary school pupils in the Netherlands.

Around the fourth year of secondary school, the pupils choose their HAVO and VWO subjects for final examination purposes. Prior to 1998, one could speak of considerable freedom of choice and, as a result, considerable variation in the subjects chosen across pupils. With the introduction of a radical change to Dutch law in 1998, this situation came to an end. Pupils must now choose one of four so-called study profiles with a unique combination of subjects each. In addition to the specific profile subjects, all of the pupils take a number of mandatory subjects, such as Dutch and English, and a number of elective subjects.

The four study profiles are as follows: culture & society (*cultuur & maatschappij*), economics & society (*economie & maatschappij*), science & health (*natuur & gezondheid*) and science & technology (*natuur & techniek*). In the two science profiles, the subjects of chemistry, mathematics B (or pure mathematics)[2] and physics are mandatory. Only certain parts of the aforementioned subject curricula are, however, involved in the science & health profile while the science & technology profile requires the curricula in their entirety[3].

In Table 1.1, the percentages of HAVO and VWO pupils are presented per study profile divided according to sex. The percentages concern the entire population of HAVO and VWO pupils in the Netherlands completing the final examinations for the relevant profiles in the school year 2001/2002. Inspection of the figures shows fewer HAVO pupils to choose a science profile than VWO pupils. In addition, for both levels of secondary education, less than 4% of the girls choose a science & technology profile as opposed to some 26% of the boys. The science & health profile is, in contrast, chosen by more girls than boys. The distributions of the national figures according to other background characteristics, such as ethnicity or social class, are simply not available. From our own research (see Chapter 2, 3 and 4), however, we know that maths and science choice also varies according to social class: children of high educated parents choose more maths and science than children of low educated parents. The influence of ethnic origin on maths and science choice by contrast, has been found to decrease over the years in our research.

Table 1.1 – Percentages of HAVO and VWO pupils per study profile according to sex (boys, girls, total) for final examination population from 2001/2002 school year. Source: CFI [4]

	Boys	Girls	Total
HAVO	N=15,419	N=18,602	N=34,021
culture&society	9.7	50.3	32.0
economics&society	49.9	29.9	39.0
science&health	13.5	16.6	15.2
science&technology	24.5	2.1	12.3
Combination	2.4	0.9	1.6
VWO	N=10,620	N=13,044	N=22,664
culture&society	6.0	32.0	20.2
economics&society	39.0	30.6	34.4
science&health	21 2	31.8	27.0
science&technology	28.2	3.7	14.7
Combination	5.6	2.0	3 6

Other CFI figures not presented here, also show only a very small percentage of those pupils not choosing a science profile to take one or more maths or science subjects on an elective basis. About 5% of the pupils from Table 1.1 with a non-science profile, for example, chose the complete or partial physics curriculum for final examination purposes.

Prior to 1998, mandatory combinations of subjects did not exist. Besides, only 6 (HAVO) or 7 (VWO) subjects had to be selected for final examination purposes while the number of final examination subjects is now around 12. For this reason, I will limit myself to a comparison of the present percentage of pupils choosing a science profile to the earlier percentage of pupils including not only maths B but also physics and chemistry in their final examination subjects. Comparable access to higher forms of follow-up education are more or less provided by these two study arrangements. As part of the national so-called VOCL'93 cohort, some 20,000 pupils in the first year of Dutch secondary school in 1993/1994 were followed. More than 5000 of the pupils from this cohort completed the HAVO or VWO final examinations either before or during the 1999/2000 school year. The subjects selected for final examination purposes were chosen around 1996. Some 18% of the HAVO pupils selected the subjects of maths B, physics and chemistry for this purpose (30% of the boys, 9% of the girls), and some 27% of the VWO pupils selected the subjects of maths B, physics and chemistry for this purpose (33% of the boys, 22% of the girls). More pupils thus chose a science profile in 2002 (Table 1.1) than the three subjects of maths B, physics and chemistry in earlier years.

Unfortunately, a comparison of the participation figures from Table 1.1 to those for other western countries is also not really possible. This is due to the major differences in the education systems across countries (see Chapter 5). Countries strongly differ, for example, in the extent to which one can speak of so-called 'streaming' or 'tracking' (i.e., the homogeneous grouping or 'pre-sorting' of pupils according to level of achievement. As a result, the participation figures for maths and science education do not always concern comparable categories of pupils. Other differences which hinder a comparison of participation figures concern such aspects of the education systems as complete freedom of subject choice versus mandatory subjects or mandatory combinations of subjects, the number of subjects to be chosen for final examination purposes, total subject offering and the provision of maths and science education at a single versus different levels.

What can be seen, in any case, for the upper levels of secondary education in other western countries is the marked lack of participation of girls in maths and science education relative to boys. The situation in the Netherlands is thus not unique. That is, a lag exists elsewhere but not necessarily to the same extent.

1.2.2 The participation in STEM courses in Dutch higher education

Higher tertiary education in the Netherlands consists of a university education (WO, *wetenschappelijk onderwijs*) or a higher professional education (HBO, *hoger beroepsonderwijs*). According to the international Organization for Economic Cooperation and Development (OECD, 1999), both forms of higher education belong to the 1997 International Standard Classification of Education (ISCED97) level 5a of tertiary education. The WO in the Netherlands is nevertheless more oriented towards theory and research than the HBO, which is much more practice oriented and thus 'applied.' Pupils with a secondary education VWO diploma are, in principle, given direct access to both HBO and VWO in the Netherlands while pupils with a HAVO diploma only have access to HBO. For some fields of study, admission depends on the study profile followed during secondary school or the particular final examination subjects.

In Table 1.2, the distributions of both full- and part-time students across the different HBO and WO sectors for the 1995/96 and 2003/04 school years are presented according to sex. When the Total columns are compared for the two years, the relative participation in the 'Technology' sector at the level of HBO can be seen to have declined by about 4% in favour of the 'Economics' sector. Nevertheless, the absolute number of HBO 'Technology' students has remained the same because the total number of HBO students showed about a 25% increase during the intervening period. In the same period, the relative participation of students in the 'Science' and 'Technology' sectors at the level of WO also slightly declined but, as a result of the growth in the total number of WO students, the absolute numbers of students in the sectors remained about the same. Other than suggested by the Dutch media at times, a major decrease of interest in STEM courses of study has thus not occurred (cf. van den Broek & Voeten, 2002). Major shifts have, however, occurred within the various sectors: within the WO 'Technology' sector, for example, the share of students studying Architecture has doubled while the shares of students studying Mechanical Engineering, Electrical Engineering and Technical Mathematics have declined enormously. As a result of this situation, there is indeed a threat of specific employment shortages (Kabinetsnota, 2003; ROA, 2003). Besides, the Dutch government is striving – in keeping with the European Union – towards growth and not continuity in the STEM sectors.

As can be seen in Table 1.2, the participation of women in STEM courses of study at both the levels of HBO and WO in both years lags considerably behind the participation of men[5]. For the national figures, divisions other than those according to sex are simply not available although the Student Monitor from 2003 (van den Broek, Kerstens, Hulsen & Sijbers, 2004) detected small differences in STEM participation depending on parental level of education and the ethnic backgrounds of students.

In the annual reports from the OECD, participation in higher education is also compared across countries for different fields of study. In Chapters 5 and 6 of this thesis, the relevant figures from these sources are reported. Compared to most western countries, the low to very low STEM participation of students in the Netherlands stands out. This holds for not only the relative participation of students in STEM courses with respect to other sectors but also for the share of female STEM students. Considerable differences within the other countries also exist, but virtually no country shows such low scores as the Netherlands.

Table 1 2 – Percentile distributions of students enrolled in HBO and VWO across different sectors in 1995/1996 and 2003/2004 according to sex Source CBS (Central Bureau for Statistics, The Netherlands)

	1995/1996			2003/2004		
HBO	Men	Women	Total	Men	Women	Total
Agriculture	4 9	2 2	3 6	3 1	2 0	2 5
Technology	34 1	6 0	20 3	30 0	4 3	16 6
Health care	3 3	12 9	8 1	3 7	12 7	8 4
Economics	31 8	24 2	28 1	40 4	28 3	34 1
Social care	6 8	20 9	13 8	5 6	17 7	11 9
Art	6 1	7 5	6 8	5 5	6 4	5 9
Education	12 9	26 2	19 4	11 7	28 6	20 5
Total (N=100%)	137,400	132,400	269,800	160,200	174,300	334,500
WO	Men	Women	Total	Men	Women	Total
Agriculture	2 9	2 6	2 8	2 3	2 3	2 3
Science	9 7	5 1	7 6	9 1	4 3	6 7
Technology	22 1	5 1	14 3	22 7	5 1	13 9
Health	8 2	13 6	10 7	8 8	16 3	12 5
Economics	21 1	8 5	15 3	23 1	9 8	16 5
Law	14 4	17 4	15 7	11 5	14 9	13 2
Behaviour & society	12 0	25 8	18 3	12 5	29 3	20 8
Language & culture	9 3	21 4	14 9	9 9	17 2	13 4
Other	0 4	0 5	0 4	0 6	0 9	0 7
Total (N=100%)	95,200	80,900	176,100	94,900	92,700	187,600

1.3 Theoretical framework

1.3.1 Introduction

The next three chapters in this thesis are concerned with research on the determinants of maths and science subject choice among upper level secondary school (i e , HAVO and VWO) pupils in the Netherlands both before and after the introduction of the mandatory study profiles In the two chapters after that, international differences in the choice of higher STEM courses stand central In all of the relevant studies, explanations are sought for the underrepresentation of certain groups As indicated in the preceding sections, such underrepresentation certainly holds for females As will be seen in the following chapters, unequal participation in maths and science education in the upper levels of secondary education is also found for pupils from different social classes and – to a lesser extent – for ethnic minority pupils We take such systematic underrepresentation to be an expression of unequal educational opportunities and, in the present section, present a global theoretical framework for understanding this situation.

1.3.2 Forms of educational inequality

Education plays a key role in the distribution of positions within society via its qualification, selection and allocation functions. In the 1960s, the fact that education was not equally accessible to all groups of society and that differences in the opportunities for such groups thus occurred received widespread international recognition. In the Netherlands, the Talent Project from van Heek et al. (1968) marks the starting point of interest on the part of researchers and policy-makers in the phenomenon referred to as inequality of educational opportunities or, in short, educational inequality.

In most cases, the differences across social groups in opportunities to attain a higher level of education are meant or what is often referred to as the vertical inequality of educational opportunities. The research along these lines is typically aimed at determining which aspects of the earlier school career predict the final level of educational attainment. Among the aspects examined are: achievements in primary and secondary school, grade repetition, early dropout, final examination results and achieved level of secondary education. The most well-known disadvantaged groups in connection with vertical educational inequality are pupils from lower social-economic classes and ethnic minorities. Girls initially belonged to the group of disadvantaged pupils as well, but their vertical educational position has improved considerably (Rowe, 2003).

In addition to vertical inequality, horizontal educational inequality can also be distinguished. This form of inequality concerns the differences between groups with respect to the distribution across educational sectors, which may lead – given comparable vertical positions – to unequal opportunities for further training, education and employment. Research on horizontal educational inequality is aimed predominantly at those points in the school career where pupils progress in different directions as a result of decision and selection procedures with particular study and professional prospects either being opened or closed as a result.

The unequal participation of groups distinguished according to sex, social class and ethnic background in higher secondary and tertiary maths and science studies is interpreted within the context of this thesis as a form of horizontal educational inequality. In general, the number of higher education follow-up possibilities increases to the extent that pupils in the upper levels of secondary education have chosen more maths and science subjects. In addition, the professional perspectives of STEM students in most western countries appear to be relatively favourable due to the previously mentioned international shortage of higher educated STEM personnel on the employment market.

With regard to the situation in the Netherlands, Bosker already demonstrated more favourable follow-up prospects for a selection of maths and science subjects in 1990 And this situation still exists. In 2003, for example, pupils with a HAVO diploma for a science & technology study profile had access to 160 of the 188 HBO courses of study being offered in the Netherlands (LICA, 2003) For a science & health profile, 157 HBO courses were accessible; for an economics & society profile, 133 courses; and for a culture & society profile, 117 courses. The inclusion of maths and science as elective subjects also improves one's prospects for educational follow-up: pupils with an economics & society profile are admitted to 8 extra courses when they have successfully completed maths B as part of their final examination subjects.

Some doubts can nevertheless be raised about the interpretation of unequal participation in STEM studies as a reflection of unequal educational opportunities Hustinx (1999), for example, points out the attachment of greater value to maths and science achievement than – for instance – language achievement with the admission requirements for higher education thus involving relatively more maths and science subjects In the opinion of Hustinx, such biased selection constitutes a form of discrimination and is quite widespread in western society although very artificial and culturally determined. Also, it can be argued that the link between field of study and employment prospects is sensitive to market fluctuations and that the more favourable prospects for STEM graduates are therefore not fixed, by definition.

Nonetheless, in the period in which the studies described in this thesis were conducted (i.e , 2002-2005), the educational and societal opportunities for individuals choosing maths and science subjects and a STEM field of study were definitely larger than for individuals choosing from a number of other subjects and courses. Besides, from the perspective of the meritocratic educational ideal (see next section), the distribution of pupils across different levels of education and fields of study should generally be a consequence of personal accomplishment and not cultural, social or economic factors

1.3.3 Theories of educational inequality

Since the beginning of the 1960s, educational inequality research has been constantly developing The relevant theories are partly complementary and partly in opposition (i e , competition)

One explanation which stems from the earliest years is that educational inequality is a consequence of inborn differences in talent (Jensen, 1969). This deterministic approach has been strongly criticized over the years but was still applied in 1994 by Herrnstein and Murray to explain the social disadvantages of ethnic minority groups in the USA. The biological differences between men and women are also regularly cited as an explanation for the observed sex differences in maths and language achievement. These achievement differences are nevertheless too small to account for the large differences in choice of subjects and courses observed for the sexes.

Opponents of the biological hypothesis assert that talent or aptitude cannot be measured in a purely context-independent manner and that the social environment strongly determines the development of potential talent (e.g., Jencks, 1972; Bronfenbrenner & Ceci, 1994; Sternberg, 1998). The discussion of the relative weights of innate predispositions versus environmental influences is referred to as the 'nature-nurture debate.' Reproduction theory emerged from this debate around 1970 and asserts that the educational inequality which exists in connection with social class – which was originally of most interest – continuously reproduces itself as a result of primary and secondary socialization processes (Bowles & Gintis, 1976). The primary socialization process operates via child rearing within the family: Depending on the cultural and social resources available to the family, a child develops a set of norms, values, behaviours and intellectual/cognitive skills. The child then brings all of these to the school situation where the secondary process of socialization then starts. The social-cultural climate of schools reflects the lifestyles of the dominant groups in society (Bourdieu, 1977). And as a consequence of this situation, pupils from higher social classes have an advantage over pupils from other classes – that is, the social-cultural capital provided by schools generally fits the baggage of pupils coming from higher as opposed to other social classes better. Pupils from lower social classes do not have the necessary baggage and also do not receive the support of the family when placed in a position to acquire this baggage via the school. In such a manner, the school careers of pupils from higher social classes are typically more successful than the school careers of pupils from lower social classes and education simply reproduces already existing inequalities (Bros, 2001).

That the socialization process breeds not only vertical but also horizontal educational inequality was already explicated by Boudon in 1974. More specifically, Boudon distinguished between the primary and secondary effects of social stratification. The primary effects concern the influence of social-cultural circumstances on the achievements of individuals while the secondary effects concern the influence of circumstances on the choice behaviour of individuals. It is the secondary effects which result in pupils from different social classes making different educational choices even when achievement is the same. That is, the analyses of the relevant costs and benefits of particular educational choices by these individuals can generate very different results The children of the economically elite will, for example, frequently opt for commercial or financial subjects and fields of study simply because they expect maximum support from their families in doing this and also perceive the subjects and studies to have a higher status on the basis of their backgrounds (van der Werfhorst, Sullivan & Cheung, 2003)

Reproduction theory was originally applied to predominantly explain the unequal participation in education depending on social class When large numbers of ethnic minority children later entered the educational systems in many western European countries in the 1970s and 1980s, reproduction theory also appeared to explain their delayed educational positions as well In fact, ethnic minority groups came to be treated as a new social class Via the notion of sex-specific socialization within the family and the school, reproduction theory also developed points of connection for the explanation of educational inequality depending on sex (Eccles, 1985, Jonsson, 1999)

Opponents of reproduction theory view education as a means to mobilize individuals and emancipate the lower classes with the abolishment of educational inequality as a result The meritocratic educational ideal of selection in education on the grounds of personal aptitude and individual accomplishment (i e , *merit* (Young, 1958)) as opposed to the social group or sex of pupils emerged out of this emancipation line of thinking Critics, however, argue that inequality would remain but simply on the basis of a different distribution formula (Goldthorpe, 1997) Yet another point of debate is what, exactly, should be understood as aptitude or individual accomplishment Some argue that aptitude includes, in the widest sense of the word, not only achievement but also such attitudinal characteristics as motivation, effort and interest (Meijnen, 2004) Others reject this standpoint on the grounds that such attitudinal characteristics are not purely aptitude related but also the result of socialization (Dekkers, 2002)

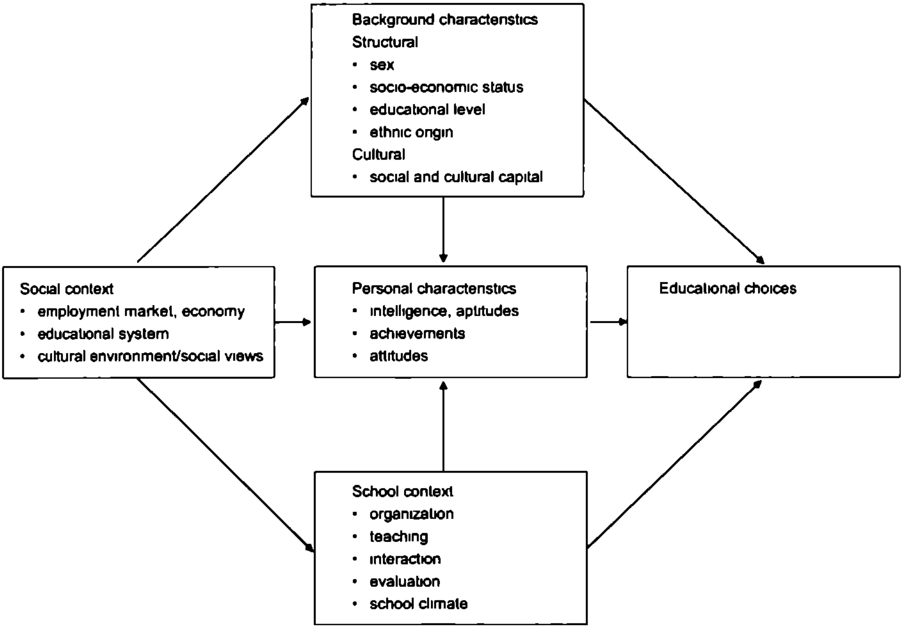
During the last decade of the twentieth century, the meritocratic calibre of education in most western countries has greatly increased as revealed by the school career research which was also initiated at this time The connections between capacities and school success grew, and education became much more accessible for children from lower social classes and ethnic minority groups The lagging participation of girls in the upper levels of secondary education even changed into a slight lead on boys (Rowe, 2003)

At the same time, there is still always talk of a reproductive element Large-scale cohort research has demonstrated a substantial link between the social and ethnic backgrounds of pupils, on the one hand, and such vertical school career variables as achievement and the final level of education attained, on the other hand Horizontal educational inequality or the unequal distribution of groups of pupils across subjects, courses and sectors has also not disappeared. And in addition to social class and ethnic background, sex is still an important – if not the most important – predictor of such horizontal inequality.

1.3.4 Determinants of subject choice

Over the course of the years, numerous studies in both the Netherlands and abroad have been conducted on the determinants of educational choice including explanations for the sex differences in the selection of maths and science subjects, courses and sectors. On the basis of the outcomes of these studies, Dekkers (2002) developed a global interdisciplinary model of those variables which can jointly explain the sex differences in educational choice. The model builds on Eccles (1985) who viewed subject choice as primarily an outcome of socialization and internalization but with less of an eye to the relevant characteristics of the school and the social context. In Figure 1.1, a more general version of Dekker's model – which is thus applicable to differences other than those according to sex in the choice of subjects, courses and sectors – is presented.

Figure 1.1 – Explanatory model for educational choice (derived from Dekkers, 2002)



The different groups of variables distinguished in Figure 1.1 can – in principle – be analyzed in light of the meritocratic-reproductive opposition, although this has generally only been done implicitly – if at all – in research to date.

In addition to sex, not only social class and ethnic background belong under 'background characteristics' but also the social-cultural characteristics related to such. The influence of background characteristics on educational choices is, moreover, by definition evidence for the reproductive calibre of education.

'Personal characteristics' include intelligence and achievements which, from a meritocratic point of view, should determine both the educational choices and success of pupils. In addition, such attitudinal characteristics as interest, motivation and effort belong to the category of 'personal characteristics,' but the legitimacy of their influence on educational choices and school success is very much open to question. Such attitudinal characteristics can, that is, be construed as indeed related to innate aptitude and personal merit or, alternatively, as a product of – at least in part – socialization.

With regard to the characteristics at the level of the school and the social context, the question is predominantly whether they reinforce or neutralize the reproductive effects of social and cultural background factors. If they are found to neutralize the effects of such, then they clearly speak in favour of the meritocratic calibre of education.

1.4 Introduction of specific research questions

The choice of maths and science subjects and science profiles by upper level secondary education pupils

In Chapters 2, 3 and 4, the determinants of the choice of maths and science subjects (i.e., science profiles) by those pupils in the upper levels of Dutch secondary education (i.e., HAVO and VWO) stand central. The studies have all been conducted in the Netherlands, which means that the most left block reflecting the influence of the social (national) context on educational choice in Figure 1.1 has no role to play. The characteristics of the social context do not vary within the research group. Of major concern in these studies, thus, is the influence of the three middle blocks – 'background characteristics,' 'personal characteristics' and 'school context' – as an explanation for the differences in choice of subjects and study profiles.

The research questions examined particularly in Chapters 2 and 4 are very similar. In both chapters, the influence of the personal capacities versus social-cultural backgrounds of pupils on their maths and science choice is examined. However, the pupils studied in Chapter 2 were still free to choose virtually all of their subjects for study while the pupils studied in Chapter 4 were required to choose one of the four study profiles introduced in 1998 (see section 1.2.1 of this chapter). The variables to be explained thus differ for the two studies. In the first study, the dependent variable is the number of maths and science subjects chosen; in the other study, it is the degree of maths and science in the chosen study profile. In both studies, the relative influences of sex, social class and ethnic origin, on the one hand, and the achievement and capacities of the pupils, on the other hand, were first examined as an explanation for the maths and science choice. In such a manner, the reproductive versus meritocratic functions of education were evaluated in their most sober forms. Thereafter, whether or not the other variables at the levels of the pupil, parents and school influenced the choice of maths and science studies was examined along with the extent to which the findings provide supplemental evidence for the reproductive or meritocratic calibre of education. The following two research questions thus underlie both Chapters 2 and 4.

a) *What are the relative contributions of sex, social and ethnic background versus capacities and achievement to the choice of maths and science subjects (Chapter 2) or a science profile (Chapter 4) for pupils in the upper levels of secondary education?*

b) *What other factors at the levels of the pupil, family and school appear to influence the observed differences in choice?*

The research described in Chapter 3 initially concerned the same two research questions as in Chapter 2 but then for only those pupils in the highest level of secondary education (i.e., VWO). The relevant results later formed the basis for the supplemental analyses described in the second part of Chapter 3 which addresses the process aspect of subject choice. More specifically, the process of choosing maths and science subjects by VWO pupils is explored with the aid of causal ordering on the basis of the path analysis models formulated to include the significant pupil and parent variables. Given that the results reported in the first part of the chapter showed the choice of maths and science subjects by VWO girls to clearly proceed differently than the choice of maths and science subjects by VWO boys, special attention is paid to this. The additional questions for consideration in Chapter 3 are thus as follows.

c) *What is the course of the causal relations between the pupil and family characteristics found to be significantly related to the choice of maths and science subjects?*

d) *Do the causal models found to explain the number of maths and science subjects chosen differ for boys and girls?*

Cross-national differences in the participation of students in STEM education

In Chapters 5 and 6, the results of two international comparative studies are described Explanations for the differences across countries in the participation of students in higher STEM education are sought (also see section 1 2 2 of this chapter) In both studies, the left block in Figure 1 thus stands central or, in other words, the influence of different social contexts on educational choices

The research reported on in Chapter 5 is of a qualitative nature Four countries which appear to differ to a fair extent with respect to general participation and the participation of women, in particular, in STEM courses were selected for more detailed comparison On the basis of interviews and analyses of various government, research and other written reports, which of the social context characteristics of the four countries appear to provide an explanation for the observed cross-national differences in educational choice is examined The research question addressed in Chapter 5 is thus as follows

e) *How can the general and sex-specific differences in the choice of higher education STEM courses across countries be explained and to what extent does the choice of maths and science subjects in upper secondary education play a role?*

The topic of Chapter 6 is again cross-national differences in the participation of women in higher STEM education The research described in this chapter is quantitative, however, and based on the available test scores for 15-year-old pupils from a number of countries Only one aspect of the social context is examined in particular the size of the gender achievement gaps or, in other words, the relative distance between the average test scores for the boys with respect to the girls in each country Whether or not the cross-national variation in the size of the gender achievement gaps relates to the cross-national differences in the later STEM participation of females is first examined Thereafter, just which characteristics of the social context appear to be associated with the national gender achievement gaps is examined And attention is also devoted to whether the gender achievement gaps vary between schools within countries and which characteristics of the schools appear to be related to this The specific research questions for Chapter 6 are thus as follows

f) *To what extent can one speak of a gender gap in maths, science and reading literacy across schools and countries and, at the level of the country, is there a relation between the size of the gender achievement gaps in secondary education and female STEM participation in tertiary education?*

g) *Are the observed gender achievement gaps associated with particular characteristics of the schools or countries?*

In the final chapter of this thesis, Chapter 7, the general research results are summarized. Conclusions are drawn with respect to the results as a whole. And the implications of the conclusions viewed from a meritocratic perspective are formulated.

Notes Chapter 1

1. In the meantime, it has become apparent that the Lisbon objectives will very likely not be achieved in time. This was, for instance, observed by the former chair of the European Commission, Prodi, upon his departure in October 2004 and farewell interviews in the Financial Times and The Wall Street Journal.

2. From the fourth year of Dutch upper level secondary education on, the subject of mathematics is divided into mathematics A and mathematics B. Maths A is more applied and thus less abstract than maths B which is also sometimes referred to as 'pure maths.'

3. This distinction has been made since 1998 but is going to be abolished in 2007. The HAVO study does not involve a partial chemistry curriculum; for the two science profiles at the level of HAVO, thus, the complete chemistry curriculum is mandatory.

4. The figures in Table 1.1 stem from the CFI (*Centrale Financiën Instellingen*). The task of this national organization is to assemble and disseminate both quantitative and qualitative figures. Pupils completing the old style final examinations in the school year 2001/2002 have been omitted from the table (n=1176). The figures with respect to 'Combination' encompass all pupils who have chosen such a set of mandatory and elective subjects for final examinations that in fact relates to two study profiles.

5. At the level of WO, this is much more the case for 'Technology' than for 'Science'. The 'Science' sector encompasses the Pharmacy and Biology courses which actually have a higher representation of women than men.

2 Group-related differences in the choice of mathematics and science subjects*

2.1 Abstract

The more mathematics and science subjects are included in the curriculum in upper secondary education, the higher the number of accessible follow-up studies provided. The meritocratic calibre of secondary education is threatened when groups of pupils distinguished according to sex, social and ethnic background but with otherwise equal capacities and achievement differ with regard to their maths and science subject choice. This theme is examined with the aid of a cohort of over 2200 pupils in the higher levels of Dutch secondary education by using multilevel analyses and multicategorical response models. The results show some groups definitely have a lower chance of choosing maths and science subjects than other.

2.2 Introduction

As in many western countries, educational policy in the Netherlands is aimed at the provision of equal opportunities for all pupils. Pupils must be given the opportunity to maximally develop themselves in accordance with their talents. But although education is open – in principle – to all pupils, it is clear that a number of processes inside and outside the educational system operate to give certain groups of pupils fewer opportunities than others.

In this chapter, the inequality of educational opportunities in relation to the choice (or take-up) of mathematics and science subjects in the two upper levels of secondary education will be considered further. Pupils in the Netherlands can choose from a greater number of possible routes in tertiary education when they have selected relatively more maths and science subjects for inclusion in their final examination package in upper secondary education. The number of maths and science subjects selected can thus be viewed as an indicator of school success. When groups of pupils are distinguished on the basis of sex and family background (i.e., social class and ethnic origin) but have otherwise comparable capacities and

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academic achievement levels, systematic group differences in the number of maths and science subjects selected can be seen as (leading to) an inequality of educational opportunities.

2.3 Formulation of the research questions

Within the Dutch secondary education system, the VWO (*voorbereidend wetenschappelijk onderwijs*; pre-university secondary education) constitutes the highest level and takes six years. The level directly thereafter is called the HAVO (*hoger algemeen voortgezet onderwijs*; senior general secondary education) and takes five years. Pupils in these two levels of education undergo final examinations in at least six (HAVO) or seven (VWO) subjects and select these subjects around their fourth year[1].

Even when pupils in HAVO or in VWO complete an equivalent level of education, by passing their examinations, one can still speak of differences in their further educational and societal opportunities as a consequence of differences in their specific take-up of subjects for inclusion in their final examination package. Certain subject choices offer a broader range of tertiary educational opportunities and thereby greater chances on the employment market. This is specifically the case for three subjects: chemistry, mathematics B (or pure mathematics) and physics[2]. The number of possible tertiary educational routes strongly increases with the number of these maths and science subjects included, because the final examinations for these subjects more frequently meet the specific admission requirements for the Dutch programs of higher education than the final examinations for the remaining subjects.

A lower number of maths and science subjects selected by some groups of pupils as compared to others with the same capacities and achievement is societally undesirable because the foundation is laid for social inequality with respect to future educational perspectives and chances on the employment market. Such unequal access is also economically unwelcome in light of the current shortage of technical and exact schooled personnel.

Traditionally, educationally deprived groups are pupils from lower social-economic classes, minority pupils and girls. The most well-known form of educational inequality with respect to maths and science subject choice concerns the latter group. Many years ago, it was observed that girls – after control for their achievement levels – showed much less of an inclination to choose maths and science subjects than boys (Dekkers, 1985; Eccles et al., 1985). Although girls in most western countries have caught up considerably in the domain of education with respect to boys during the past decades (OECD, 2003; Rowe, 2003), this tendency is still visible today (Radford, 1998; Arnot, David & Weiner, 1999; Jonsson, 1999; Smyth & Hannan, 2004). During the past years, the interest of boys in maths and science subjects has also declined. The sex differences in take-up of maths and science subjects remain so large, however, that it is very unlikely that they can be completely explained by differences in capacity alone.

Over the past decades, considerable research has been undertaken internationally to explain variation in (maths and science) subject choice in education. Much of this research concerns only a few variables and is more or less mono-disciplinary. The research reported here is based on a large-scale national cohort. In such a manner, pupil, family, and school variables can all be involved in the analyses at the same time. Attention can be paid to not only sex differences but also the influence of social and ethnic background in addition to the interactions between these various factors.

The underlying research questions are thus as follows:
1. To what extent do differences in the take-up of maths and science subjects, that cannot be traced back to differences in capacities and achievement, occur between groups of pupils, distinguished according to sex and family background, in the higher levels of Dutch secondary education?
2. Which other factors at pupil, family, and school levels that are related to individual capacities and merits on the one hand or to social or demographic group characteristics on the other hand appear to influence the observed choice differences?

In the following, an overview of the theoretical background behind these questions and the international research findings with regard to the take-up of maths and science subjects will be presented. Thereafter, the research method and results of the analyses will be described. And in closing, the findings will be summarized and a number of conclusions will be drawn.

2.4 Theories of educational inequality

The research questions formulated above fit into a long tradition of research on educational inequality in connection with membership in a particular social or demographic group. Since the start of educational inequality research in the 1960s, the combating of educational disadvantage has been the topic of heated debate between the advocates of two different lines of thought, which are known as the reproduction versus emancipation theories (Coleman et al., 1966; Jencks, 1972). Reproduction theory boils down to education reproducing the existing social inequality via qualification, selection, and allocation according to sex, social class and ethnic background. (van Zanten, 2003) This approach encompasses the theories of cultural and social capital (Bourdieu, 1977; de Graaf, de Graaf & Kraaykamp, 2000), which state that the cultural and social resources available to the pupil through his family contribute to the success of a pupil at school. According to emancipation theory, in contrast, education can reduce social inequality via the promotion of individual mobility. This approach is related to the meritocratic ideal that education would allow pupils to earn a social position on the basis of their capacities or talents (their 'merits') and not their social or ethnic background or sex (Young, 1958). Critics, however, argue that inequality would remain but simply on the basis of a different distribution formula (Goldthorpe, 1997). Yet another point of discussion concerns the concept of capacities as the soundness of this concept and the influence of the social environment on such has not gone undisputed (cf. the nature-nurture debate). At present, the reproduction and emancipation theories are not diametrically opposed to each other; one can speak of a kind of equilibrium between the two theories (Mortimore, 1997; Sternberg, 1998).

How relate the aforementioned theories to the research questions in the present study? In fact, the first question tests the reproduction thesis and meritocratic ideal in their "barest" form: to what extent are pupil differences in the take-up of maths and science subjects explained by differences in capacities and achievement on the one hand and by differences in group characteristics on the other hand? The number of maths and science subjects chosen is taken, in this case, to be an indicator of school success due to the association with increased number of possible future routes. The larger the differences in choice of maths and science subjects between groups according to sex, social and ethnic background, the more reproductive Dutch secondary education is. And the meritocratic caliber of Dutch secondary education thus comes under fire when group differences in the choice of maths and science subjects are still present after controlling for individual capacities and achievement.

With the second research question, additional explanations for the observed differences between pupils in their take-up of maths and science subjects will be sought. In fact, these explanations lie in an extension of research question 1. The pupil characteristics examined for their influence on the subject choice can relate to largely inborn characteristics – comparable to the previously mentioned capacities – but also to largely learned characteristics – via socialization within one's gender, social or ethnic group. If the latter characteristics appear to explain differences in the take-up of maths and science subjects, then primarily the reproduction thesis is confirmed. This also holds for the family characteristics that we consider. Finally, the school variables examined here can constitute a concrete operationalization of either reproductive or meritocratic education, depending on their character.

2.5 International research findings

Prior to our analyses, a review of the international research literature was undertaken to identify which determinants are generally posited to explain the differences in the take-up of maths and science subjects The results will be presented below in terms of five groups of factors distinguished for our research question group characteristics, capacities and achievement, and other pupil, family, and school characteristics Much of the research we found was explicitly concerned with the sex differences in subject choice and, for this reason, considerable attention will be paid to this

2.5.1 Group characteristics

Social class

The evidence for the influence of social class on school achievement and career is abundant while the relations to subject choice are less clear Dekkers, Bosker, and Driessen (2000) found the educational level of the parents of pupils in the higher levels of secondary education to play virtually no role in explaining subject choice Uerz, Dekkers, and Beguin (2003), however, found an effect in the direction of a more frequent take-up of maths and science subjects by pupils with higher educated parents

Ethnicity

Dekkers et al (2000) detected little influence of ethnicity on the take-up of subjects, but Uerz et al (2003) found non-minority pupils in the Netherlands to select maths and science subjects significantly more frequently than minority pupils The latter finding parallels the findings reported in the US by Muller, Stage, and Kinzie (2001) However, Hanson and Johnson (2000) detected a surprising interaction between ethnicity and sex, with African-American girls showing a more positive attitude towards science and better achievement than expected

Sex

In many western countries, research findings comparable to those for the Netherlands are reported Boys choose more maths and science subjects than girls (Colley, 1998, Arnot, David & Weiner, 1999, Jonsson, 1999, Smyth & Hannan, 2004) The sex differences are not equally large in all countries, however, nor is the gender gap equally large for each of the subjects within countries (van Langen & Dekkers, 2005a, 2005b)

2.5.2 Capacities and achievement

Intelligence, aptitude

Sex differences in aptitude for mathematical and scientific thinking as an explanation for differences in achievement and subject choice has been the topic of heated debate over the past decades. Maccoby and Jacklin concluded in 1974 that such biological or neurological differences may indeed exist. However, these differences can hardly be found anymore today or are now too small to explain the large differences in subject choice between the sexes (Hedges & Nowell, 1995; Fennema, 1996). The previously mentioned nature-nurture debate is also relevant here: Are measured differences actually a consequence of aptitude or perhaps due to the social environment or test bias? The debate is not limited to sex differences, moreover. Herrnstein and Murray (1994) speak of genetic differences in aptitude between ethnic groups while opponents put forth differences in material conditions and child-rearing styles and cultural test bias as an explanation.

Achievement

The discussion regarding sex differences in achievement parallels that regarding aptitude. In the past, it has been repeatedly asserted that girls score higher in the area of language and reading while boys score better in the area of maths and science (Johnson, 1996). At the same time, however, the relevant achievement differences are not so large that they can explain the differences in subject choice between the sexes (Dekkers et al., 2000; Roger & Duffield, 2000). On the basis of the SIMS/TIMSS (Second/Third International Mathematics (and Science) Studies) and PISA (Programme for International Student Assessment) studies, moreover, it can be concluded that the sex differences in maths and science achievement have decreased greatly over the past few years (Baker & Jones, 1993; Gray, 1996; OECD, 2003).

An explanation for the lower maths achievement of women from a feminist perspective is that the manner of mental processing differs for males versus females (Fennema, 1996). That is, the maths that we know today is thought to be primarily masculine, male-dominated maths that does not fit the manner in which females think and learn.

Jonsson (1999) and Uerz et al. (2003) have shown relative skill to also play a role in subject choice; that is, a person's skill in one subject relative to his or her skill in other subjects.

2.5.3 Other pupil characteristics

Attitude

According to the social-psychological explanatory model for educational choices developed by Eccles et al (1985), it is not so much the objective experiences as the subjective interpretation of such that influence the estimates of one's own competence and the expectations of success and, in the end, the process of subject choice Roger and Duffield (2000) point out that the value attributions and estimated own competence of the pupil are under the influence of socialization by parents, peers, and teachers Jonsson (1999) developed a rational-choice model in which the take-up of subjects is determined by the chances of success, utility, and costs and benefits of each subject according to the pupil Elsworth, Harvey-Beavis, Ainley, and Fabris (1999) have asserted that both interest and enjoyment (i e , "intrinsic value") and estimated utility (i e , "extrinsic value") in connection with a particular subject equally influence the choices of boys and girls but that boys tend to find maths and science subjects more interesting, more fun, and more useful than girls

Personality characteristics

Estimated own competence is associated with the self-images of pupils and the causal attributions of success and failure that stem from such (Weiner, 1986) Girls appear to attribute their failure at maths to a lack of capacity while boys attribute this to bad luck or lack of effort Conversely, girls explain their success at these subjects to coincidence or luck while boys attribute this to talent (Eccles et al , 1985, Muller et al , 2001)

The learning styles of boys and girls also differ according to some researchers (Fennema, 1996, Forbes, 1996) Girls flourish in a cooperative lesson environment and tend to prefer subject matter for which they can see the social relevance and/or applicability to their daily lives The usual instruction in maths and science, in contrast, typically fits the competitive lifestyle of boys and may therefore explain sex differences in subject take-up

2.5.4 Other family characteristics

Family composition

Smeets and Dekkers (1996) could not detect an effect of growing up in a single-parent family on the take-up of maths and science subjects Others have found family composition to influence maths achievement and general educational position (Kraaykamp, 2000, Uerz et al , 2003)

Family culture

Van der Velden (1991) could not trace back differences in the choice of subjects to differences in cultural capital or sex-role socialization within the family. Dekkers (1990) found a relation between the take-up of maths and science subjects by girls and the profession and education of their mothers. Eccles et al. (1985) and Smeets and Dekkers (1996) studied the views of parents with regard to the suitability and competence of their children for a number of maths and science subjects and found the views of the children to mirror the views of their parents. Eccles et al. then proposed that parental opinions are more directly related to a child's self-concept and expectations for the future than his or her actual achievement in the past is.

2.5.5 School characteristics

School context

Dekkers et al. (2000) have observed that in schools with more boys than girls in the school population, more maths and science subjects tend to be chosen by all of the pupils when compared to other schools. In research by Elsworth et al. (1999), the subject physics was chosen increasingly more often as the pupil population of a school stemmed from an increasingly higher social class. Dekkers (1985) previously found girls from rural schools to choose more maths and science subjects than girls from urban areas.

School organization

In 1985, Dekkers found girls to make more maths and science choices in schools where the leadership was more educationally involved than in other schools. Bosker (1990) found boys in goal-oriented, cohesive schools to make a subject choice with significantly more follow-up education perspectives (i.e., with more maths and science subjects) than boys in other schools; but this did not hold for girls.

Since the 1980's the quality of the curricula is also subject of study to explain gender attitudes towards the maths and science subjects in light of the previously mentioned differences between the sexes with regard to learning styles (van Eck & Veeken, 1986; Roger & Duffield, 2000). For the same reason the composition of sex-homogeneous (maths) classes is sometimes pleaded for, but the effects of such a homogeneous class arrangement have yet to be demonstrated unequivocally (Daly, 1996).

A factor specifically related to subject choice is selection guidance by the school (Smyth & Hannan, 2004). According to Kristensen and Jenneskens (1991), those schools with the highest rates of maths and science subject choice by girls tend towards a certain degree of steering instead of 'laissez-faire'. An explicit emancipation-oriented school policy does not appear to influence the take-up of maths and science subjects by girls (Bosker, 1990).

Finally, the level of secondary school appears to be of relevance for the take-up of maths and science subjects: The higher the level, the smaller the sex differences are (Kuyper, van der Werf & Lubbers, 1999).

Teacher and class

Roger and Duffield (2000) could find no evidence that the achievement and choices of girls are stimulated by the presence of a female maths teacher. The influence of sex stereotyped expectations, judgments, recommendations, and behaviour on the part of teachers on the subject choices and particularly the take-up of maths and science subjects by girls has stood central in many studies but produced mixed results (Colley, 1998; Stokking, 2000). Equally equivocal are the results of research on the differential effects of the didactic methods used by teachers on the achievement and attitudes of particularly girls within the areas of maths and science (Forbes, 1996; Kahle, 1996; Sobolewski & Doran, 1996).

2.6 Method

2.6.1 Description of the database

For the present study, use was made of the data from a large-scale national cohort, the VOCL'93 (Secondary Education Student Cohort 1993; Brandsma & van der Werf, 1997). The pupils in the cohort were followed from their first year of secondary school in 1993/94. On an annual basis, information with regard to their type of school and academic year was requested from the schools; starting in 1997/98, the results of their last year of final examinations including the subject choice were also requested. In addition, Dutch language and maths tests and an IQ test were administered to the pupils in the first academic year and the pupils, parents and school directorates were asked to complete a written questionnaire. In 1995/96, Dutch language and maths tests were again administered to the pupils experiencing no delays and a questionnaire was again completed by the pupils, parents and school directorates. The response in this third year of secondary school study was considerably lower than in the first year.

The present research pertains to those pupils from the VOCL'93 cohort completing their final examinations for the two highest levels of secondary education (i.e., HAVO and VWO) in 2000 at the latest. In principle, this was 2887 and 2200 pupils, respectively. Of these, 98% indeed reached the third year of secondary school without delay. Due to non-response, however, only about 45% of the pupils completed the maths test at this time. We therefore selected this part of the research sample for further analysis in order to minimize the influence of missing values on the independent variables. In the end, the analyses were based on 1299 pupils from 63 HAVO schools and 987 pupils from 55 VWO schools.

The representativeness of the final sample was examined by testing for differences between the selected and non-selected pupils (α=0.01) for all of the pupil variables collected during the first year and included in our analyses (see next section). The results of these analyses showed the selected HAVO pupils to be non-minority slightly more often than the non-selected pupils (9% versus 6%) and their average score on the non-verbal IQ test to be one point higher than the average score for the non-selected pupils (56 versus 55 on a scale of 0 to 80). The VWO pupils differed slightly with respect to the average level of education for the mother; this was 0.2 points lower for the selected pupils relative to the non-selected pupils on a scale of 2 to 6. The representativeness of the schools was next examined (α=0.05) for all of the school variables included in the analyses. The selected schools only appeared to provide a slightly smaller range of study and career guidance activities than the non-selected schools (p=0.047).

2.6.2 Selected variables

The dependent variable in the present analyses was the number of maths and science subjects included in the final examination selection of subjects by the HAVO and VWO pupils[3]. From the data collected in the first and third years, 40 possibly explanatory variables were selected (cf. Table 2.1). Following logically from our research question, the variables included were first and foremost those pertaining to sex, social class, ethnicity, capacities and achievement. Second, it was attempted to select as many other pupil, family and school variables with proven relevance – according to the review presented above – and included in the database. Unfortunately, no relevant teacher or class characteristics were available. Third, some additional variables were included that are known to relate to not so much subject take-up as to school achievement and career – as indicated in the VOCL'93 reports from Brandsma and van der Werf (1997), van der Werf, Kuyper, and Lubbers (1999), and Veenstra (1999). The assumption behind this is that a pupil's choice of subjects is influenced by his or her achievement and that variables influencing achievement may thus indirectly influence subject choice as well (cf. Daly & Ainley, 1999). Finally, a few school characteristics that directly pertain to – the guidance of – subject choice and may therefore, logically, influence the course of such were included. Given that these characteristics were hardly found in the research literature and therefore not mentioned in the review, our hypotheses with respect to their influence are also explicated.

In the following, the selected variables will be briefly described, again in terms of the five groups of factors distinguished for our research question: group characteristics, capacities and achievement, and other pupil, family, and school characteristics. Only the construction of the newly created variables will be further explicated. The remaining variables and scales are described in the aforementioned VOCL'93 reports, which also supplied a number of the Cronbach's alphas reported here.

Table 2.1 – Overview of explanatory variables selected

Group characteristics sex parental level of education ethnicity *Capacities and achievement* non-verbal IQ score maths score Dutch language score *Remaining pupil characteristics* enjoyment of Dutch language enjoyment of maths child level of educational aspiration self-image achievement motivation maths/science orientation language orientation motivation of subject choice relative maths-language skill	*Remaining family characteristics* maternal education employment experience of mother single-parent family first-born child number of books in home sex-role opinions of parents child-rearing style: autonomy granted talk about school parental level of educational aspiration for child *School context and organization* size of school degree of urbanization for community male/female pupil ratio average level of parental education general school climate substantive educational involvement of school directorate team consensus offering of elective subjects for final examination	*School characteristics with respect to subject choice* minimum requirements for subject choice range of study and career guidance offered involvement of guidance counsellor involvement of subject teachers involvement of grading committee importance of grades importance of personal desires importance to recommendations of subjects with best follow-up possibilities

Group characteristics

The variable parental level of education (i.e., highest educational level in the family) was drawn from the parent questionnaire in year 1 as an indicator of social class. Also selected were sex and ethnicity of the pupils. Given the relatively small number of minority pupils in the database, ethnicity was boiled down to a dichotomy: non-minorities and minorities from western countries versus minorities from non-western countries (i.e., ethnic minorities).

Capacities and achievement

Selected for analysis were the non-verbal IQ test score measured in the first year, and the scores on the maths and Dutch language tests in the third year.

Remaining pupil characteristics

A number of characteristics on attitude and personality characteristics were drawn directly from the pupil questionnaire administered during the third year: enjoyment of maths and Dutch language (1=unpleasant to 4=very enjoyable), the aspired final level of education, self-image (α=.75), and achievement motivation (α=.77). In both the first and third years, the pupils were asked to indicate whether they expected to include each of a number of subjects in their final selection of subjects. In the first year, the pupils are far from the actual point of selection; their answers are therefore taken to provide an indicator of general interest. This produced an "maths/science-oriented scale" (expect to choose chemistry, maths and physics; α=.65) and a "language-oriented scale" (expect to choose modern languages; α=.63). A follow-up question concerned the main reasons for the indicated pattern of selection expectations; not per subject but in general. The response categories for this question from the third year were then transformed into a dichotomy of subject choice based on intrinsic versus extrinsic motives. In addition, a relative skill variable was constructed by calculating the differences between the Z scores for the maths and Dutch language tests.

Remaining family characteristics

The following characteristics on family composition and familiy culture were drawn from the parent questionnaire administered during the first and third years: the level of education and number of years of employment experience for the mother; growing up in a single-parent family and being the first born child; the number of books in the home; the sex-role opinions of the parents (α=.78) and the child-rearing style of the parents (i.e., the degree of autonomy granted the child) (α=.74); the frequency with which the parents and child talk about school (α=.79); and the parental aspirations with respect to the final educational level of the child.

School context and organization

The size of the school (i e , total number of pupils) and the degree of urbanization for the community in which the school is located were selected as context variables in addition to the male/female pupil ratio and the average parental level of education for the school population in the first year General school climate was calculated as the average of the individual school experiences of the pupils reported during the first year (α= 81)

From the school directorate questionnaire, the variables substantive educational involvement of the school directorate, team consensus, and offering of elective final examination subjects[4] were selected for inclusion in the analyses The first variable is derived from the question regarding the distribution of available directorate time across 11 clusters of activities with 4 of the clusters concerning educationally substantive matters The second variable is calculated on the basis of the extent to which regulations are established for the teachers for 10 domains (e g , application of disciplinary measures, assignment of homework, α= 72) The third variable was chosen on the basis of the assumption that a wider range of elective subjects to choose from can lead to a lower take-up of maths and science subjects

School characteristics with respect to subject choice

The school directorate questionnaire contained questions directly concerned with the guidance of subject choice A number of the characteristics revealed by these questions were selected for inclusion in the analyses Given that such characteristics are rarely mentioned in the research literature, they will first be described and our hypotheses with respect to their influence then explicated below

- The imposition of minimum requirements on pupil achievement to allow take-up of a subject We expect this variable to be of particular relevance for boys due to their relatively high estimates of their own competence and of the utility of maths and science subjects, which will generally predispose them to choose these subjects even in cases of low achievement
- The range of study and career guidance offered A wide range will lead to a well thought out choice of subjects as the follow-up perspectives are also taken into consideration and thus more maths and science subjects
- The involvement of a guidance counsellor (as opposed to the student adviser[5]) for individual discussions with pupils and parents with respect to study and career options and the supply of information to pupils Our assumption is that the guidance counsellor has less personal contact with pupils but a broader view of the total study and career picture, which means greater attention to the future perspectives for pupils and less attention to their personal desires We thus expect the involvement of a guidance counsellor to lead to greater take-up of maths and science subjects
- The involvement of individual subject teachers and the grading committee[6] in advising with regard to the subject choices We suspect that the involvement of subject teachers will lead to subject choices on the basis of actual achievement

and thereby better use of the maths and science capacities With respect to the involvement of the grading committee, we assume that this may call for justification of the recommendations made by colleagues at times, correct for sex-stereotyped prejudices regarding the suitability of maths and science subjects for girls, and lead to more recommendations for girls in particular to choose those subjects

- The importance that the directorate attaches to the grades (i e , report marks) as opposed to the personal desires of the pupil during subject choice The more the grades and the less the personal desires are taken into consideration, the greater the number of maths and science subjects chosen
- The importance that the directorate attaches to recommendation of those subjects with "the best follow-up possibilities" Considerable importance indicates attention to the maximum number of follow-up educational perspectives and thus take-up of the greatest number of maths and science subjects possible

2.6.3 Set-up of the analyses

The analyses were conducted for the two groups of pupils according to their level of secndary education (i e , HAVO and VWO) separately This was technically necessary as their basic curricula differ The HAVO pupils are required to have a minimum of six subjects for final examination purposes and the VWO pupils a minimum of seven (see also Note 1)
The relations between the selected variables and the number of maths and science subjects chosen were initially examined univariately with the aid of Spearman correlations and Chi-square tests In such a manner, it was possible to gain an impression of the strength of the rough connections between the various characteristics and the selection of subjects In general, the connections were stronger for the VWO pupils than for the HAVO pupils, which emphasizes the importance of conducting separate analyses Multivariate analyses were subsequently undertaken in order to map the effects of the pupil, family, and school characteristics in combination Use was made of multiple level analyses due to the hierarchical structure of the dataset pupils are grouped within schools Family characteristics are actually of the same level as the pupil's And because the number of maths and science subjects could vary from zero to three, the analyses were based on ordered multicategorical response models (see also Appendix A)

The analysis procedure involved a number of steps First, the effects of the group variables of sex, parental level of education, and ethnicity and the interactions between these variables on the number of maths and science subjects chosen were examined The influence of the capacities and achievement were also taken into consideration by correcting for non-verbal intelligence and the scores on the maths and Dutch language tests Possible differences that could not be traced back to differences in the capacities and achievement of the groups of pupils could thus be detected The results of this first step provided the answer to the first part of our research question

In the second step of the analyses, the remaining pupil, family, and school variables were added to the initial model as described in the next section This resulted in the final model, which provided us with an additional explanation for the differences in subject choice detected in the first step of the analyses and thereby the answer to the second part of our research question

2.7 Results

2.7.1 Group differences in the choice of maths and science subjects

The multilevel analyses began with the fitting of an ordered multicategory response model containing no explanatory variables whatsoever (the empty model) The distribution of the number of maths and science subjects predicted on the basis of this model largely corresponded to the distribution detected in the raw data The empty model was then expanded with the explanatory variables of sex, parental level of education, ethnicity and the first- and second-order interaction terms for these variables By correcting for non-verbal intelligence and the scores for Dutch language and maths, the influence of capacities was controlled for (Model 1) A summary of the findings is presented in Table 2 2, where only the significant effects are presented The score for the Dutch language test can be seen to be absent, apparently this is of little or no relevance for the take-up of maths and science subjects

The proportion variance explained (R^2) in Model 1 for the HAVO pupils was 0 17, for the VWO pupils, this was 0 18 (see also Appendix A)

For the HAVO pupils, sex and parental level of education were found to be strongly related to the dependant variable Boys chose more maths and science subjects than girls, and pupils with high educated parents chose more maths and science subjects than pupils with low educated parents In contrast, the influence of ethnicity was not significant when sex and parental level of education were already included in the model The effects of sex and level of education continue to exist when the capacities and achievement of the pupils have been corrected for None of the interaction terms whatsoever proved significant

Table 2.2 – Multilevel analyses results for explaining number of maths and science subjects chosen (Model 1). Parameter estimates (standard error) reported for significant variables only

	HAVO	VWO
Sex (0=girl, 1=boy)	1.216 (0.117) **	3 441 (0 675) **
parental educational level	0.179 (0.064) **	0.538 (0.105) **
ethnicity (0=non-minority, 1=minority)		3.181 (1.083) **
Sex * parental educational level		-0.520 (0.139) *
Sex * ethnicity		-3.103 (1.464) **
parental educational level *ethnicity		-0.711 (0.235) **
Sex * parental educational level * ethnicity		0.735 (0.327) *
IQ score	0.024 (0.006) **	0.022 (0.006) **
maths test score	0.022 (0.004) **	0.035 (0.005) **

* sign p<0.05; ** sign. p<0.01

For the VWO pupils, the main effects of sex, parental level of education, and ethnicity and all of the interaction terms related significantly to the take-up of maths and science subjects. The associations continued to exist when the capacities and achievement of the pupils were taken into consideration. Expansion of the model to include the interaction terms involving IQ and the maths test scores did not seem justified as none of these proved significant.

Given the significant interaction terms, subgroups of VWO pupils could be distinguished for which the associations with the number of maths and science subjects chosen clearly differed. In Table 2.3, the influence of the interaction terms on the distribution of the number of maths and science subjects selected by the VWO pupils while assuming average IQ and maths test scores is presented.

For the VWO boys, the number of chosen maths and science subjects hardly depends on the parental level of education or ethnicity. For the VWO non-minority girls, however, few maths and science subjects are chosen in the case of a low level of parental education; in the case of a high level of parental education, the distribution of the number of maths and science subjects chosen greatly resembles the distribution for the VWO boys in general. The situation for the minority VWO girls is the reverse but less extreme. Minority VWO girls choose more maths and science subjects in the case of a low level of parental education as opposed to a high level of parental education.

Table 2 3 – Predicted number of maths and science subjects for VWO pupils according to sex, ethnicity and parental level of education with IQ and maths scores held constant

	Number m & s subjects	boys %	girls %
Non-minority			
low parental education	0	31 9	83 8
	1	15 2	7 0
	2	23 2	5 5
	3	29 7	3 7
high parental education	0	30 4	37 6
	1	15 0	15 8
	2	23 4	21 9
	3	31 2	24 8
Minority			
low parental education	0	29 3	47 1
	1	14 8	15 8
	2	23 6	18 9
	3	32 4	18 2
high parental education	0	25 9	64 0
	1	14 0	13 2
	2	23 9	12 8
	3	36 1	10 0

2.7.2 The influence of remaining pupil, family, and school variables

All of the remaining characteristics at the levels of the pupil (Model 2a), family (Model 2b), and school (Model 2c) were next added to Model 1 The school variables were added to the model as fixed variables at the level of the schools Even if there appears to be no significant variance at the school level, it is possible that school variables explain part of the variance at the pupil level The reverse is not possible

Only a few of the variables originally selected for analysis "survived" the significance test at this step in the analyses and were subsequently added simultaneously to Model 1 to produce Model 3 All of the effects found for Models 2a, 2b, and 2c showed virtually the same size and direction for Model 3 The final step in the analyses followed next Model 1 showed three of the four relevant interaction terms to include the sex of the pupil In order to gain greater insight into this finding, the preceding steps in the analyses were repeated separately for boys and girls The newly relevant variables revealed by these sex-specific analyses have

been added as a main effect and an interaction term with sex to Model 3. The resulting model is the final model (Table 2.4; see also Appendix A).
In Appendix B, all of the variables from this model are described. The proportion variance explained by the final model was 0.33 for the HAVO pupils and 0.43 for the VWO pupils.

Table 2.4 – Multilevel analyses results for explaining number of maths and science subjects chosen (final model). Parameter estimates (standard error) reported for significant variables only

	HAVO	VWO
Group characteristics		
sex (0=girl, 1=boy)	1.444 (0.177) **	3.648 (0.762) **
parental educational level	0 130 (0.066) *	0.572 (0.113) **
ethnicity (0=non-minority, 1=minority)		3.479 (1.149) **
sex * parental educational level		-0.625 (0.148) **
sex * ethnicity		-3.149 (1.535) *
parental educational level * ethnicity		-0.759 (0.250) **
sex * parental educational level * ethnicity		0.694 (0.342) *
Capacities and achievement		
IQ score	0.013 (0.006) *	0.018 (0.007) **
maths test score	0.015 (0.004) **	0.031 (0.005) **
Pupil characteristics		
enjoyment of maths	0.793 (0.080) **	0.810 (0.087) **
enjoyment of Dutch language		-0.356 (0.095) **
maths/science orientation	0.596 (0.095) **	0.558 (0.107) **
language orientation	-0.216 (0.081) **	-0.323 (0.105) **
motivation of subject choice (0=intrinsic, 1= extrinsic)	0.534 (0 183) **	0 564 (0.196) **
Family characteristics		
child rearing style	0.259 (0.108) *	0.265 (0.122) *
parental level of aspiration		0.122 (0.054) *
School characteristics		
degree of urbanization	c	-0.286 (0.097) **
involvement of grading committee		-0.673 (0.222) **
Interactions with sex		
motivation of subject choice * sex	-0.680 (0.257) **	-0.928 (0.272) **
involvement of grading committee * sex		0.782 (0.275) **

* sign. $p<0.05$; ** sign. $p<0.01$; c = unable to calculate due to convergence problems

All of the main effects from Models 2a, 2b, 2c and 3 also occur in the final model. For both the HAVO pupils and the VWO pupils, it is the case that enjoyment of maths during the third year and both the maths/science orientation and language orientation during the first year (with the latter being negative) significantly predicted the number of maths and science subjects chosen The child-rearing style of the parents exerted a small but significant effect Furthermore, three variables were found to play a significant role for the VWO pupils but not for the HAVO pupils enjoyment of Dutch language during the third year of study (negative), the parental level of aspiration (positive), and the degree of urbanization for the community in which the school is located (negative) Note that for the HAVO pupils, the effect of the degree of urbanization could not be estimated The model does not reach convergence as the addition of this variable results in all of the random parameters being set to 0 during the iteration process

In addition, the final model contains two variables that stood out in the sex-specific analyses First, one can speak of an interaction between motivation of subject choice and sex for both the senior general secondary and VWO pupils The influence of this interaction term was as follows girls with an extrinsic motive chose more maths and science subjects than girls with an intrinsic motive The reverse holds for boys but to a weaker extent boys with an extrinsic motive chose fewer maths and science subjects than boys with an intrinsic motive A second significant interaction was found to occur between sex and involvement of the grading committee in subject-choice guidance, but in only the final model for the VWO pupils Our hypothesis was that such involvement would lead to a higher choice of maths and science subjects among the girls Inspection of the data shows the interaction to be other than expected The VWO girls in schools where the grading committee was involved in the guidance of subject choice chose fewer maths and science subjects than the VWO girls in schools where the grading committee played no such role Among the VWO boys, the number of maths and science subjects chosen simply did not depend on the involvement of the grading committee

The main effects of the background variables are stronger for the VWO pupils than for the HAVO pupils This is in keeping with the results of the exploratory univariate analyses, which also showed the raw connections to be stronger for the VWO pupils Furthermore, the percentage variance explained by the final model was higher for the VWO pupils than for the HAVO pupils This suggests that subject choice behaviour and the influence of the school program on this are better predicted by the variables identified on the basis of theory for VWO pupils than for HAVO pupils

2.7.3 Differences between schools

In the multi-level analyses, the variance among the different HAVO schools and the variance among the different VWO schools did not prove significant Schools of the same type thus differ very little with respect to the number of maths and science subjects chosen by the pupils Nevertheless, we determined the extent to which the

10% schools with the smallest number of maths and science subjects selected on average differed from the 10% schools with the largest number. The difference appeared to be 0.58 maths and science subjects for the HAVO schools and 0.86 for the VWO schools. Although the school variance was non-significant, almost one maths or science subject was chosen less on average at some of the VWO schools.

With the inclusion of sex, parental level of education, and – for the VWO schools – ethnicity as random variables at the level of the school in Model 1, the extent to which the connection between these variables and the dependant variable varied across schools could be examined. None of the random effects proved significant: schools of the same type do not differ with respect to the relation between sex, parental level of education, and – for the VWO schools – ethnicity and the number of maths and science subjects chosen.

2.8 Summary and conclusions

The greater the number of maths and science subjects a pupil chooses for final examination, the greater the number of future educational routes available to him/her and thereby the greater his/her chances on the employment market. Stimulation of an maths and science subject choice may seem to be unnecessary when a pupil knows precisely which non-exact direction he or she wants to pursue at a later date. But systematic differences in the take-up of maths and science subjects – after correction for capacities and achievement – across groups of pupils distinguished on the basis of such background characteristics as sex, ethnicity, and social class cannot be the coincidental sum of such individual preferences. In other words, one could certainly speak of group-related educational disadvantages. And as research by Kuyper et al. (1999) has shown, moreover, a substantial portion of those pupils who think that they know which follow-up study they want to pursue prior to the subject choice actually make other plans within a period of two years.
To what extent do differences in the maths and science subject choice that cannot be traced back to differences in capacities and achievement occur between groups of pupils in the highest levels (i.e., HAVO and VWO) of Dutch secondary education? The results from the analyses suggested that we can indeed speak of significant group-related choice differences. Given comparable capacities and achievement, the chances of a favourable subject choice in HAVO are lower for girls and pupils from lower social backgrounds than for boys and pupils from higher social backgrounds. In VWO, the take-up of maths and science subjects by boys is not influenced by ethnic or social background while the take-up of those subjects by girls is indeed influenced by such and particularly by the parental level of education.

Which other factors at the pupil, family, and school levels appear to influence the observed differences in subject choice? At the level of the school, only 2 variables were found to contribute to the explanation of the maths and science subject choice First, a higher degree of urbanization for the community in which the school is located was negatively related to the number of maths and science subjects chosen Given that this is a context characteristic, few policy conclusions can be connected to it Second, the VWO girls at schools where the grading committee played a role in the guidance of subject choice chose fewer maths and science subjects than the VWO girls at schools where this was not the case One explanation for this finding may be that the possible weaknesses of girls – in contrast to our a priori hypothesis – are considered in a sex-role reinforcing manner during such meetings
Characteristics of the family that appear to have a limited but significant effect on the number of maths and science subjects chosen concern child-rearing style and, for VWO pupils, also the parental level of educational aspiration for the child

The majority of the characteristics that – in addition to the previously discussed group characteristics, capacities, and achievement – exerted a significant effect on the take-up of maths and science subjects concerned the pupil An orientation towards maths and science subjects and modern languages in the first year of secondary study and the pupil's enjoyment of maths and – for only the VWO pupils – Dutch language in the third year were significant predictors of the number of maths and science subjects chosen Also at the level of the pupil, the interaction between motivation of subject choice and sex was found to play a role Girls with an extrinsic motive were more likely to choose maths and science subjects than girls with an intrinsic motive For boys, the effect of choice motivation is the opposite and not as strong Boys choose fewer maths and science subjects when the choice is extrinsically motivated Underlying this finding are again sex differences with respect to interest and enjoyment in connection with maths and science subjects Only when girls ignore those intrinsic values do they choose maths and science while boys who allow themselves to be guided by interest and enjoyment choose maths and science subjects At the same time, this provides an explanation for the declining interest in maths and science subjects among boys They apparently consider subjects other than maths and science more important for their future And we may possibly see the gradual effects of government campaigns in the past encouraging girls to choose more maths and science, Girls who recognize the importance of subject choice for their future connect this, to maths and science subjects And in this case, it may have been wise to involve boys in the campaigns as well

Education is meritocratic to the extent that the school success of a pupil is determined more by his or her individual "merits" than by such characteristics as sex, class or ethnicity Even when the present research findings at the level of the individual (i e , interest, orientation, motivation of subject choice) are construed as individual merits and the influence of socialization is thus ignored (see section on theories of educational inequality above), the influence of sex, parental level of education, and ethnicity is found to remain important. The meritocratic caliber of secondary education in the Netherlands is thus at issue – at least when it comes to the take-up of maths and science subjects in the upper levels. As far as the substantive factors that may further influence this accessibility, we only have a few clues.

The take-up of maths and science subjects by the girls studied here was not only influenced by their capacities but also much more by their social and ethnic background, involvement of the grading committee, and their motivation of subject choice when compared to the boys. Despite the reports of educational success for girls we must conclude that very little has – in fact – changed over the past few decades with respect to their maths and science subject choice.

Notes Chapter 2

1 In 1998, the number of final examination subjects has changed to approximately 11 (HAVO) and 13 (VWO). At the same time, the relative freedom of subject choice became a thing of the past. HAVO and VWO pupils are now required to choose from four fixed combinations of subjects (or study profiles). However, the pupils in this study made their choice prior to 1998.

2. In Dutch secondary education, mathematics A is less in-depth than mathematics B and thus provides less access to higher education routes. In the present research it was therefore decided to include only the three 'most exact' subjects chemistry, maths B and physics and not to consider maths A further. The same goes for biology.

3. Note that by using the selected number of maths and science subjects as dependent (categorical) variable in the present analyses, we ignore the fact that gender choice differences are not equally large for all three subjects in the VOCL'93 cohort: For VWO girls the take-up percentages of chemistry, maths B and physics are 36.9%, 33.2% and 30.5%, while for VWO boys these percentages are 46.1%, 63.1% and 58.8%. For HAVO girls these take-up percentages are 25.2%, 16.4% and 17.5%, while for HAVO boys they are 38.7%, 50.7% and 46.8%.

4. Most subjects are offered as required subjects by all Dutch schools; in addition, they have a limited degree of freedom to offer other subjects for final examination.

5. Every group of pupils in Dutch secondary schools has a student adviser who is also a teacher. The student adviser monitors the academic progress of the pupils and provides support in the case of personal problems. The guidance counsellor is a school official who provides advice, information, and guidance with regard to subject and career choice.

6. A grading committee involves all of the teachers for a particular group of pupils and meets to discuss and determine the grades (i.e., report marks) for each pupil.

3 Sex-related differences in the determinants and process of mathematics and science choice in pre-university education*

3.1 Abstract

The more mathematics and science subjects pupils in secondary, pre-university education include in their final examination package, the more future academic routes are available for them. The equality of educational opportunities is thus threatened when groups of pupils, distinguished by sex and family background but otherwise of equal capacities and achievement, are found to differ in their choices. This proposition is examined using data from a large Dutch cohort. Multilevel analyses show that the choice of maths and science subjects by girls is influenced by their family background while the choice by boys is not. The influence of various pupil and family variables on the subject selection process is next explored via path analyses. The results confirm the importance of viewing subject choice as a chronological process which progresses differently for boys and girls.

3.2 Introduction

Pupils in Dutch pre-university education (VWO), which typically takes a total of six years, choose their final examination subjects in the fourth year, around the age of sixteen. The choice of subjects is important for the future courses of their school careers because admission to higher education is based on final examination results.

The pupils can choose from a greater number of possible future academic routes when they have relatively more mathematics and science subjects in their final examination package. Science, Technology, Engineering and Mathematics (STEM) courses become especially more available, since chemistry, mathematics B (or pure mathematics) and physics are the major qualifying subjects for these courses.

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* A slightly different version of this chapter has been accepted for publication in *International Journal of Science Education*. An earlier Dutch version of this chapter has been published in two articles in *Pedagogische Studiën* (2004), 81(2), 117-133 and 134-150.

The number of maths and science subjects selected for inclusion in the final examination package can thus be viewed as an indicator of school success. When groups of pupils are distinguished on the basis of sex and family background but have otherwise comparable capacities and achievement, systematic group differences in the number of maths and science subjects selected can be seen as leading to an inequality of educational opportunities.

In this chapter, this theme is further explored using data from a large-scale national cohort with information on VWO pupils, their families and their schools. First, the actual differences between groups of VWO pupils with respect to their choice of maths and science subjects are explored. The extent to which these differences can be traced back to differences in capacities and achievement and which remaining factors at the levels of the pupil, family and school, appear to play a role is addressed in multilevel analyses. Thereafter, greater insight into the actual process of subject choice and the influence of different variables on each other is sought by incorporating the pupil and family characteristics into causal models. In order to make the interaction effects involving sex more transparent, path analyses are not only conducted for VWO pupils in general but also for boys and girls separately.

3.3 Theoretical background and research questions

3.3.1 Educational inequality and the choice of maths and science subjects

We speak of educational inequality when groups of pupils with comparable capacities and achievement nevertheless have unequal chances of school success (Meijnen, 1996). Educationally disadvantaged groups are traditionally pupils from lower social-economic classes, minorities, and girls, although certain types of educational deficiencies have a relatively higher incidence among boys today (Rowe, 2003). School success is typically defined in terms of the level of education attained or school achievement. However, the number of maths and science subjects which the pupils include in their final examination package can also be taken to be an indicator of school success due to the relation to the number of possible future academic routes to be chosen from.

The most well-known form of educational inequality with respect to subject choice concerns sex. Many years ago, it was observed that girls – after control for their achievement levels – showed much less of an inclination to choose maths and science subjects than boys (Dekkers, 1985; Eccles et al., 1985). This is also the case today (Radford, 1998; Arnot, David & Weiner, 1999; Jonsson, 1999; Smyth & Hannan, 2004). The stubbornness of this phenomenon is even more striking in light of other developments: The original achievement deficits of girls with regard to maths and science have declined over the years (Baker & Jones, 1993) and, in most western countries, girls now have higher language and reading achievement and achieve a higher final educational level than boys (OECD, 2003). The interest of boys in maths and science subjects has also declined over the past few years but not to the extent that the sex differences in the choice of these subjects have disappeared (van Langen & Dekkers, 2005a, 2005b).

Over the course of the years, various determinants have been put forth to explain the choice of subjects by pupils in general and maths and science subjects by boys and girls in particular. At the level of the pupil, the most important determinants to be mentioned beyond sex are: aptitude, prior achievements, learning style, estimated competence and chances of success, interest, enjoyment, motivation and expectations for the future (e.g., Eccles et al., 1985; Arnot et al., 1999; Elsworth, Harvey-Beavis, Ainley & Fabris, 1999; Jonsson, 1999; Karlsen, 2001; Beavis, 2003; Uerz, Dekkers & Béguin, 2004). At the level of the family, the following determinants are primarily mentioned: social class; ethnic origin; family composition; and cultural and social capital (e.g., de Graaf, de Graaf & Kraaykamp, 2000; Dekkers, Bosker & Driessen, 2000; van der Werfhorst, Sullivan and Cheung, 2003; Uerz et al., 2004). At the level of the school, the following determinants are mentioned: characteristics of the curricula, didactics and teachers; school and class context characteristics; and the school guidance and advice offered with regard to subject choice (e.g., Lee, 1993; Daly, 1996; Rosenbaum, Miller & Krei, 1996; Lee, Croninger & Smith, 1997; Colley, 1998; Dryler, 1999; Roger & Duffield, 2000).

3.3.2 Subject choice as a dynamic process

In many studies, the fact that the final choice of subjects is the result of a prolonged and dynamic process involving a number of mutually influential factors at different levels is often ignored (Dekkers, 1999). This process can only be mapped with the aid of comprehensive causal models (Rumberger, 1987).

Bosker and Dekkers (1994) did consider the process side of such selection and found the originally considerable sex differences in maths achievement to the advantage of boys to decrease over the course of three years while the initially non-significant differences in the intention to select maths became significant with a much higher percentage boys than girls selecting this subject at the end. Jörg (1994) and Stokking (2000) similarly found pupils to regularly change their intended choice of subjects prior to the actual choice and that choice predictors also changed over the course of the years. Both of the latter studies are based on the social-psychological explanatory model of educational choices put forth by Eccles et al. (1985).

3.3.3 Research questions

The research reported here is based on a large-scale Dutch cohort with data on VWO pupils, their parents and schools In such a manner, multiple levels of variables could be analyzed at the same time and attention can be paid to not only sex differences but also to the influence of various family background variables and their interactions

In the first part of the present study, the relative influence of sex, parental level of education (as an indicator of social class) and ethnic origin on the number of maths and science subjects chosen is examined The number of maths and science subjects chosen is taken to be an indicator of school success due to the known association with increased number of possible future academic routes The question of whether one can speak of 'justified' or 'unjustified' differences in school success is addressed by controlling for capacities and achievement Additional explanations for the observed subject choice differences at the level of the pupil, family and school are also sought

The models used in these multilevel analyses have the disadvantage of providing only insight into one-way connections, in each set of analyses, the independent variables are brought into connection with one and the same dependent variable, namely the number of maths and science subjects chosen Another limitation is that the chronological aspect of the selection process is ignored In the second part of the present study, the pupil and family characteristics found to be significant in the first part are incorporated into causal models in order to better illuminate the process side of the subject choice Given that the choice seems to proceed so differently for girls versus boys, special attention is paid to this

The research questions underlying the study were thus as follows

1 To what extent do differences in the take-up of mathematics and science subjects, which cannot be traced back to differences in capacities and achievement, occur between groups of Dutch VWO pupils?
2 Which other variables at the levels of the pupil, family and school appear to influence the observed choice differences?
3 What is the course of the causal relations between the pupil and family characteristics found to be significantly related to choice of maths and science subjects?
4 Do the causal models for the number of maths and science subjects chosen differ for boys versus girls?

3.4 Method

3.4.1 Dutch secondary education

Children in The Netherlands enter secondary school at around the age of twelve After an initial period of two years, pupils pursue one of three possible levels VMBO (*voorbereidend middelbaar beroepsonderwijs*, pre-vocational secondary education), HAVO (*hoger algemeen voortgezet onderwijs*, senior general secondary education) or VWO (*voorbereidend wetenschappelijk onderwijs*, pre-university secondary education) Including the two-year basic curriculum, the first level takes a total of four years, the second level a total of five years, and the third level a total of six years The actual duration may be longer when pupils have to resit classes
VWO pupils select their subjects for final examinations in the fourth year, around the age of sixteen Up until 1998, at least seven academic subjects had to be selected The choice of these subjects was largely free although Dutch and at least one modern language were compulsory Nowadays, pupils must choose one out of four set subject combinations for final examination However, the pupils in our study made their subject choice prior to 1998

3.4.2 Description of the database

Use was made of the data from a large-scale national cohort, the VOCL'93 (Secondary Education Pupil Cohort 1993) The pupils in this cohort were followed from their first year of secondary school in 1993/1994 On an annual basis, information with regard to the level of education and academic year was requested from the schools Starting in 1997/1998, the results for their final school-leaving examinations including subject choice were also assembled

In 1993/1994 Dutch language, maths and non-verbal intelligence tests were administered, and the pupils, parents and school directorates were asked to complete a questionnaire In 1995/1996, Dutch language and maths tests were again administered to the pupils experiencing no delays and a questionnaire was completed by the pupils, parents and school directorates

Although the VOCL'93 cohort covers all secondary education, the research reported on here concerns only those pupils in the VWO track This is because the basic curricula for the three tracks differ considerably The analyses of the maths and science subject choice by the HAVO pupils are presented elsewhere (van Langen, Rekers-Mombarg & Dekkers, forthcoming)

The present analyses concerned those VWO pupils from the VOCL'93 cohort completing their final examinations in the year 2000 at the latest This was a total of 2200 pupils Of these, 98% indeed reached the third year of secondary school without a delay Due to mainly school-related non-response, however, only about 45% of the pupils completed the maths test at this time We selected this part of the research sample for further analysis in order to minimize the influence of missing values Thereafter, those schools with only one pupil remaining in the sample were also removed for statistical reasons In the end, the analyses were based on 987 pupils from 55 VWO schools

The representativeness of the sample was examined by testing for differences between the selected and non-selected schools (α=0 05) and pupils (α=0 01) This was done for all of the variables measured during the first year and included in our analyses (see Table 3 1) The results showed the selected pupils to differ slightly with respect to the average level of education for the mother The mothers of the selected pupils scored slightly lower than the mothers of the non-selected pupils (p=0 004)[1] The selected schools appeared to provide a slightly smaller range of study and career guidance activities than the non-selected schools (p=0 047)

3.4.3 Selected variables

The dependent variable in the present analyses was the number of examination subjects chosen from {chemistry, mathematics B (or pure mathematics) and physics} None of these subjects was selected by 44% of the pupils (girls 55%, boys 31%), 14% selected one subject (girls 13%, boys 15%), 18% chose two subjects (girls 17%, boys 20%), and 24% chose all three of the subjects (girls 15%, boys 34%)

From the data collected on the pupils, parents and directorates during the first and third year, 40 possibly explanatory variables were selected for consideration Following logically from our research questions, the variables included were first and foremost those pertaining to sex, parental level of education (as an indicator for social class), ethnic background, capacities and achievement Second, it was attempted to select as many available variables with proven relevance, according to literature, to subject choice Third, additional variables known to relate to school achievement were included The assumption behind this was that a pupil's subject choice is influenced by achievement and that variables influencing achievement may also thus, indirectly, influence subject choice as well (cf Daly & Ainley, 1999) Finally, a few school characteristics which directly pertain to subject choice were included

Table 3.1 – Overview of explanatory variables measured in years 1 and 3

Group characteristics Year 1: - sex - parental level of education (highest level between parents) - ethnicity: non-minorities (including western minorities) versus (non-western) minorities *Capacities and achievement* Year 1: - (non-verbal) IQ score Year 3 - maths score - Dutch language score *Remaining pupil characteristics* Year 1: - maths/science orientation: expect to choose chemistry, maths, physics (α=.65) - language orientation: expect to choose French, German, English language (α=.63) Year 3: - enjoyment of Dutch language - enjoyment of math - aspiration of final educational level - general self-image (α=.75) - achievement motivation (α=.77) - intrinsic vs. extrinsic general motivation of subject choice - relative maths-language skill (differences between Z-scores)	*Remaining family characteristics* Year 1: - maternal level of education - employment experience of mother - single-parent family - first-born child Year 3: - number of books in home - sex-role opinions of parents (α=.78) - child-rearing style: autonomy granted to child (α=.74) - frequency of talk about school between parents & child (α=.79) - parental aspirations of final educational level for child *School context and school organization* Year 1: - size of school - degree of urbanization for community in which school is situated - male/female pupil ratio - average level of parental education - school climate: average of individual school experience reported by pupils (α=.81) - percentage of available directorate time committed to educationally substantive matters - team consensus: extent to which regulations for teachers are agreed upon (α=.72) - offering of elective subjects for final examination*	*School characteristics with respect to subject choice* Year 1: - imposition of minimum requirements on achievement for subject choice - study and career guidance offered - involvement of guidance counsellor versus student adviser** in talks with pupils & parents about study and career options - involvement of subject teachers in advising with regard to subject choice - involvement of grading committee*** in advising with regard to subject choice - importance that directorate claims to attach to grades of pupils during subject choice - importance that directorate claims to attach to personal desires of pupil during subject choice - importance that directorate claims to attach to subject choice with best future possibilities

* Dutch schools have a limited degree of freedom to offer other than required subjects for final examination.

** A student adviser is also a teacher. He/She monitors academic progress and provides support in the case of personal problems of his pupils. A guidance counsellor is a school official who provides advice, information, and guidance with regard to subject and study choice.

*** A grading committee involves all of the teachers for a particular group of pupils and meets to discuss and determine the grades for each pupil.

An overview of the selected variables is presented in Table 3 1 For a further description, the reader is referred to Kuyper, van der Werf & Lubbers (2000), Veenstra (2004) and van Langen, Rekers-Mombarg & Dekkers (forthcoming) A number of the Cronbach's alphas reported here come from VOCL'93 technical reports (Brandsma & van der Werf, 1997, van der Werf, Kuyper & Lubbers, 1999, van der Werf, Lubbers & Kuyper, 1999)

3.4.4 Set-up of the analyses

Analyses were undertaken to map the effects of the pupil, family and school characteristics Use was made of multilevel analyses due to the hierarchical structure of the dataset And because the number of maths and science subjects could vary from zero to three, the analyses were based on ordered multicategorical response models (Goldstein, 1995, see also Appendix A)

First, the effects of the group variables sex, parental level of education and ethnic background together with the effects of the interactions between these variables on the number of maths and science subjects chosen were examined The influence of capacities and achievement were also taken into account by correcting for IQ, maths and Dutch language test scores The results of this first step provided the answer to our first research question

Next, the remaining pupil, family and school variables were added A final regression model was identified and provided us with an additional explanation for the differences in subject choice detected in the first set of analyses and thereby the answer to our second research question

Path analyses were undertaken next We initiated these with the development of a conceptual causal model including, in principle, all of the pupil and family characteristics found to be significant in the multilevel analyses[2] The procedure then followed consisted of the verification of the conceptual causal model and the adaptation of the model in such a manner that a final causal model with maximum model fit was attained[3] with all of the paths thus proving statistically significant ($\alpha<0$ 05) In such a manner, the answer to our third research question was provided

In order to make the interaction effects involving sex more transparent, the path analyses were also conducted separately for boys versus girls, taking the final causal model identified for all pupils as starting point The sex-specific models were also verified and adapted on the basis of their fit and statistically significant paths ($\alpha<0$ 10) And in such a manner, the answer to our fourth research question was provided

3.5 Results

3.5.1 Group differences in the choice of maths and science subjects

A summary of the significant findings in the first set of multilevel analyses is presented in Table 3.2, middle column. The scores for the Dutch language test can be seen to be missing; apparently they are of no relevance for the choice of maths and science subjects. The proportion of variance explained (R^2) was 0.18.

The variables sex, parental level of education, ethnic background and the interactions between these variables all related significantly to the choice of maths and science subjects. The associations continued to exist when capacities and achievement of the pupils were taken into consideration. Further expansion of the model to include the interaction terms involving IQ and maths test scores was not justified, as none of these proved significant.

Given the significant interaction terms, subgroups of VWO pupils could be distinguished for which the associations with the number of maths and science subjects chosen clearly differed. It appeared that for boys the number of subjects chosen hardly depends on the parental level of education or ethnic background. For non-minority girls, however, very few maths and science subjects are chosen by those with parents with a low level of education. The distribution of the number of maths and science subjects chosen by those non-minority girls with parents with a high level of education greatly resembles the distribution for the boys in general. And the situation for minority girls is the reverse but less extreme: Minority girls choose more maths and science subjects in the case of a low level of parental education as opposed to a high level of parental education.

Table 3 2 – Results of multilevel analyses for explaining number of maths and science subjects chosen (regression model 1, final regression model), parameter estimates (with standard error) reported for significant variables only

	regression model 1	final regression model
Group characteristics		
sex (0=girl, 1=boy)	3 441 (0 675) **	3 648 (0 762) **
parental education	0 538 (0 105) **	0 572 (0 113) **
ethnicity (0=non-minority, 1=minority)	3 181 (1 083) **	3 479 (1 149) **
sex * parental education	-0 520 (0 139) *	-0 625 (0 148) **
sex * ethnicity	-3 103 (1 464) **	-3 149 (1 535) *
parental education*ethnicity	-0 711 (0 235) **	-0 759 (0 250) **
sex * parental education* ethnicity	0 735 (0 327) *	0 694 (0 342) *
capacities and achievement		
IQ score	0 022 (0 006) **	0 018 (0 007) **
maths score	0 035 (0 005) **	0 031 (0 005) **
Pupil characteristics		
enjoyment of maths		0 810 (0 087) **
enjoyment of Dutch language		-0 356 (0 095) **
maths/science orientation		0 558 (0 107) **
language orientation		-0 323 (0 105) **
motivation of subject choice (0=intrinsic, 1= extrinsic)		0 564 (0 196) **
Family characteristics		
child rearing style		0 265 (0 122) *
parental aspirations of final child educational level		0 122 (0 054) *
School characteristics		
degree of urbanization		-0 286 (0 097) **
involvement of grading committee		-0 673 (0 222) **
interactions with sex		
motivation of subject choice * sex		0 928 (0 272) **
involvement of grading committee * sex		0 782 (0 275) **

* sign p<0 05, ** sign p<0 01

3.5.2 The influence of the remaining pupil, family and school variables

The remaining characteristics at the levels of the pupil, family and school were next added Only a few of the variables originally selected for analysis 'survived' the tests of significance at this point and were thus added simultaneously In order to gain greater insight into sex-specific relations, the preceding steps in the analyses were then repeated separately for boys and girls Newly relevant variables have been added as a main effect and an interaction term with sex The resulting model is the final regression model (Table 3 2, right column, see also Appendix A) In Appendix

B, all variables included are described in greater detail. The total percentage variance explained by this model was 0.43.

Both the language (negative) and maths/science orientation during year 1 (i.e., expressed general interest in these subjects) and both Dutch language (negative) and maths enjoyment during year 3 significantly predicted the number of maths and science subjects chosen. The child-rearing style and parental aspirations for final child educational level also had a small but significant effect. Furthermore, the degree of urbanization for the community in which the school was located was found to have a negative effect.

In addition, the final regression model contains two variables that stood out in the sex-specific analyses. The first is subject choice motivation: Girls with extrinsic motives (e.g., 'I choose those subjects which will be useful for later') chose more maths and science subjects than girls with intrinsic motives (e.g., 'I choose those subjects which I like or am good at'), while the reverse was found to hold for boys but to a weaker extent. The second is the involvement of the grading committee in subject choice guidance: Girls in schools where the grading committee was involved tended to choose fewer maths and science subjects than girls in schools where the committee was not involved. For boys, this characteristic did not influence their maths and science subject choice.

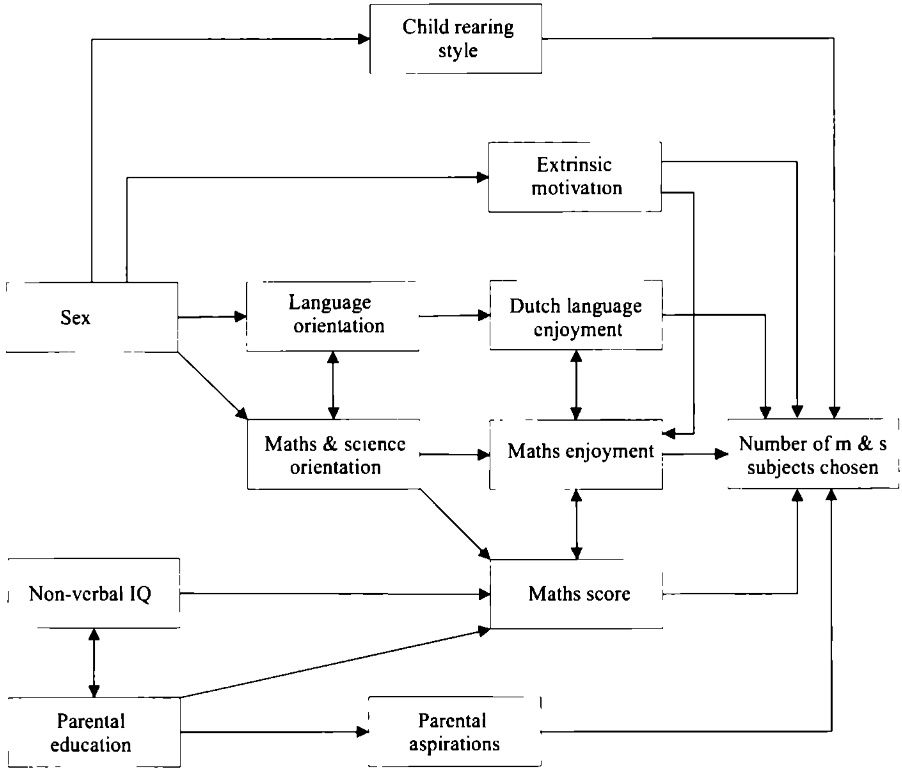
Although school variance was nonsignificant, the extent to which the 10% schools with the smallest average number of maths and science subjects chosen differed from the 10% schools with the greatest average number was next examined. The difference was 0.86: almost one subject was chosen less on average at some VWO schools than at others.

With the inclusion of sex, parental level of education and ethnic background as random variables at school level in regression model 1, the extent to which the connection between these variables and the dependant variable varied across schools could be examined. None of the random effects proved significant: VWO schools do not differ with respect to the relation between sex, parental level of education and ethnic background, and the number of maths and science subjects chosen.

3.5.3 Conceptual causal model for all VWO pupils

In Figure 3.1, the conceptual causal model which served as the starting point for the path analyses is presented. This causal model contains all of the pupil and family variables from the final regression model (i.e., Table 3.2) with the exception of ethnic background. Given that the number of minority pupils was too limited for the planned path analyses (n=81), this variable was excluded. Within the conceptual causal model, a chronological process of subject selection is presupposed, which means that pupil characteristics measured in year 1 are positioned prior to pupil characteristics measured in year 3. The arrows representing the relations between the different variables can thus, by definition, not run from right to left[4].

Figure 3.1 – The conceptual causal model



As can be seen from Figure 3.1, the language and maths/science orientations in year 1 are assumed to be interrelated just as Dutch language and maths enjoyment in year 3. We assume these variables to be at least partially complementary (Jonsson, 1999; Uerz et al., 2004). Equally obvious are the connections between language orientation and Dutch language enjoyment, as well as maths/science orientation and maths enjoyment (Elsworth et al., 1999). We further presuppose a relation between maths/science orientation and maths score in year 3 and a correlation between maths enjoyment and maths score (Dekkers, 1996). The extrinsic (versus intrinsic) general motivation for subject choice in year 3 influences maths enjoyment but not the Dutch language: Maths was not a mandatory final examination subject at the time while Dutch language was, which means that subject choice motives could play a role with respect to maths. Finally, of all the pupil variables measured in year 3, a direct arrow – indicating a direct relation – is drawn to maths and science subject choice one year later.

The exogenous variables of sex, parental education and IQ score are, in principle, stable and therefore presumably exert influence even before secondary school. Therefore, they are positioned on the far left of the conceptual causal model. A connection runs from sex to both maths/science orientation and language orientation and to subject choice motivation. In the literature, boys and girls are frequently found to differ on average in the amount of enjoyment and interest with respect to language, maths and science on the one hand, and with girls showing intrinsic subject choice motives relatively more often than boys on the other hand (Eccles et al., 1985; Dekkers, 1996). The arrow from IQ to maths score indicates the connection between aptitude and achievement; the arrow from parental education to maths score stems from the assumption that an effect of social class on achievement will be apparent even within a relatively homogeneous group of VWO pupils (de Graaf and Wolbers; 2003). For the sake of completeness, a bi-directional arrow has also been drawn between parental level of education and IQ score.

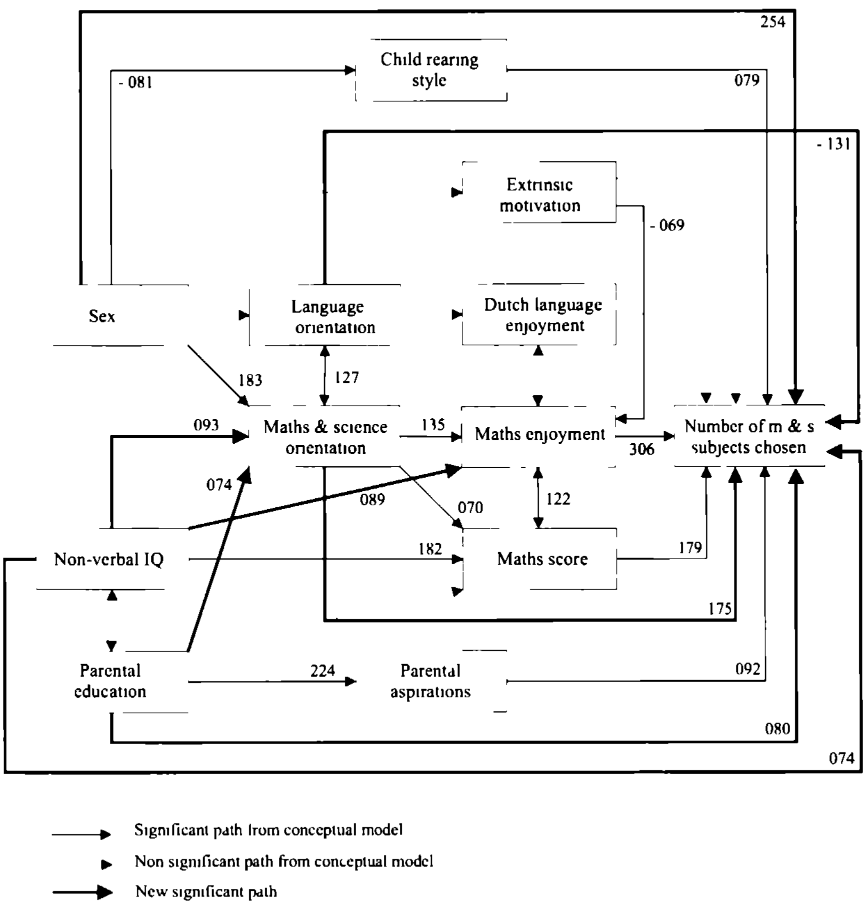
The two remaining explanatory variables concern parental aspirations and child-rearing style. Both variables were measured in year 3 but we assume the point of measurement to be of less importance for these relatively stable characteristics. With respect to parental aspirations, van der Werf et al. (1999) reports a considerable correlation (0.34) with parental level of education. Therefore, the variable is positioned between parental level of education and the dependent variable. The assumption underlying this is that the higher level of parental aspirations coming from highly educated parents leads to the choice of more maths and science subjects because of the higher number of future academic possibilities associated with these subjects. Again according to van der Werf (1999), child-rearing style hardly correlates with parental level of education – at least not within the group of VWO pupils – but significantly with sex: Girls are generally given greater autonomy than boys. Within the conceptual causal model, child-rearing style is thus positioned between sex and the dependent variable. We assume the extent to which autonomy is given to exert a direct effect on the choice of maths and science subjects.

For the sake of clarity, no direct arrows are drawn between sex, IQ score, parental education, maths/science and language orientation on the one hand and the dependent variable on the other hand. These relations are nevertheless evaluated because it is very conceivable that not all of the influence of these variables on the outcome variable occurs via mediating variables.

3.5.4 Final causal model for all VWO pupils

The conceptual causal model was supported only in part by the empirical data (RMSEA=0.044, WRMR=1.261, p=0.00). The reality of the choice process for the VWO pupils appears to be more complex than assumed. In order to attain a final causal model with an acceptable fit, five direct and three indirect relations had to be added to the conceptual model and eight relations omitted (Figure 3.2). The fit of the final causal model was good (RMSEA=0.022, WRMR=0.858, p=0.06). The percentage variance explained was 0.33. A large part of the variance (67%) thus remained unexplained. And in the following, particular attention will be paid to only those standardized parameter estimates greater than 0.10.

Figure 3.2 – The final causal model for VWO pupils with standardized parameter estimates for the paths



In the first column of Table 3 3, that part of the total effect which occurs via mediating variables is presented for each of the characteristics included in the final causal model for all pupils This is expressed as the percentage indirect effect, which means that the remaining part can be attributed to a direct effect on the number of maths and science subjects chosen

For sex, the percentage indirect effect is 7% The difference between boys and girls in the choice of maths and science subjects only depends to a very small extent on what are considered in the literature to be very important factors, namely orientation, achievement and enjoyment The extremely strong direct relation between sex and the maths and science subject choice thus occurs at the cost of a number of assumed indirect relations Sex shows no relations whatsoever via language orientation in year 1 or subject choice motivation in year 3 The indirect relations between sex and the number of maths and science subjects chosen via maths/science orientation and child-rearing style do remain, however, with the former proving most important

The final causal model also shows the influence of IQ score on the maths and science subject choice to be more extensive than assumed, as can be concluded from the 50% indirect effect (Table 3 3) The most important indirect relation between intelligence and subject choice occurs via maths score although intelligence is also found to exert an indirect effect via maths/science orientation and maths enjoyment No correlation was detected between IQ score and parental level of education

The most important indirect effect within the final causal model for all pupils is that of parental level of education via parental aspirations Higher educated parents have higher aspirations for their child, and this leads to a greater choice of maths and science subjects on the part of the child than for lower educated parents All of the indirect connections considered together still remain less important than the direct connection between parental level of education and the number of maths and science subjects chosen (74%, see Table 3 3)

It was also found, in contrast to what we hypothesized, that to the extent that a pupil was more maths/science oriented, the more language oriented he or she also was It should be noted, in closing, that Dutch language enjoyment was not present in the final causal model for all pupils considered together In the sex-specific causal models considered below, however, the situation will be found to be different

Almost all of the variables from the conceptual causal model with the exception of subject choice motivation and Dutch language enjoyment can be seen to exert a direct effect on the number of maths and science subjects chosen (see Figure 3 2 and Table 3 3) Of all these direct relations, that with maths enjoyment was the most important followed by those with sex, maths score and maths/science orientation Maths enjoyment correlates with the latter two variables as well

Table 3.3 – Overview of the percentage indirect effect as a proportion of the total effect of the particular pupil or family characteristic on the number of maths and science subjects chosen

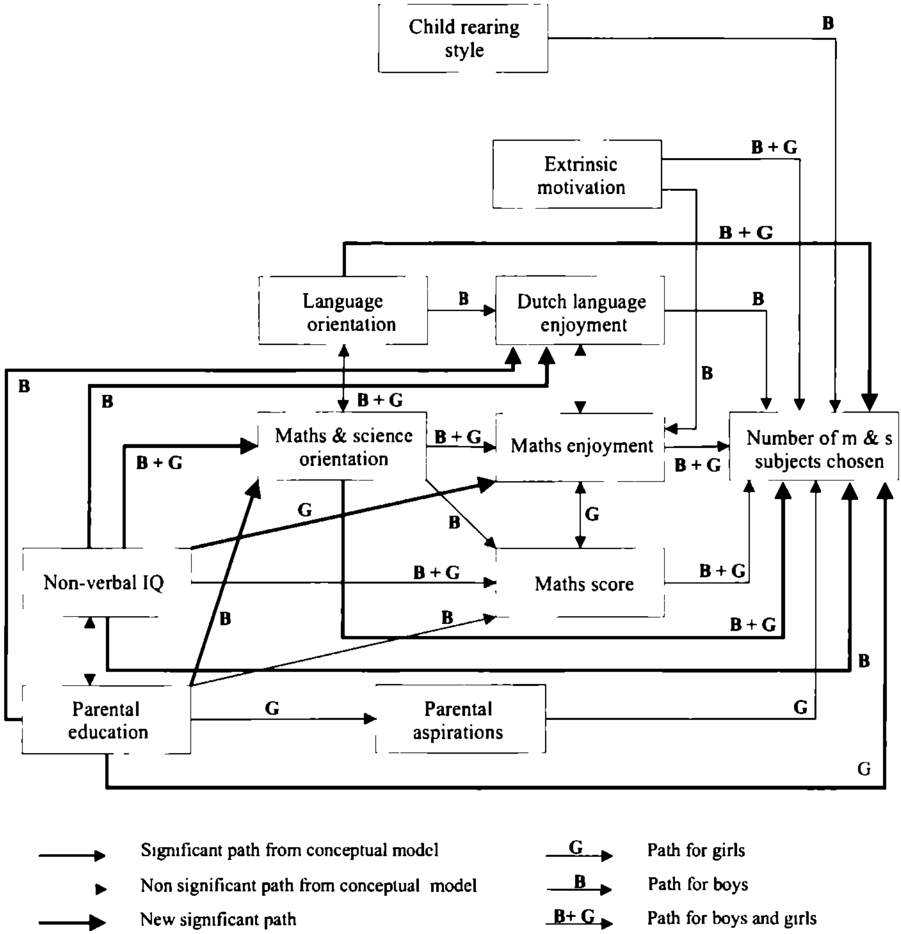
	Final causal model (Figure 3.2) %	Final causal model boys (Figure 3.3) %	Final causal model girls (Figure 3.3) %
Group characteristics.			
Sex	7	n.a.	n.a.
Parental education	26	100	11
Capacities and achievement:			
IQ score	50	34	100
Maths score	17	0	25
Pupil characteristics.			
Maths/science orientation	30	40	22
Language orientation	19	27	22
Enjoyment of Dutch language	n.a.	0	n.a.
Enjoyment of maths	7	0	10
Extrinsic motivation of subject choice	100	25	0
Family characteristics:			
Child rearing style	0	0	n.a.
Parental aspirations	0	n.a.	100

n.a.: not applicable

3.5.5 Sex-specific causal models

The final causal model for all VWO pupils constituted the starting point for the causal modelling for boys and girls separately. After verification, adaptation and expansion, two final causal models containing only significant paths were attained. The fit of both models was good (boys: RMSEA=0.029, WRMR=0.790, p=0.11; girls: RMSEA=0.000, WRMR=0.688, p=0.51). The total amount of variance in the dependent variable explained was 0.28 for boys, 0.35 for girls. The test of whether the model for the boys also holds for the girls was negative (RMSEA=0.060, WRMR=1.146, p=0.00)[5]. In other words, the maths and science subject selection process indeed proceeds differently for girls versus boys.

Figure 3.3 – Path diagrams for the final causal models for both the VWO boys and VWO girls



The differences between the two causal models and the differences which they bear with respect to the conceptual causal model are depicted in Figure 3.3. In Table 3.4, the nonstandardized coefficients for the various relations are presented.

Table 3.4 – Nonstandardized coefficients for significant relations in final causal models for VWO boys and girls

	Boys	Girls
maths score → number of maths & science subjects chosen	0.015	0 015
enjoyment of maths →number of m & s subjects chosen	0.396	0.420
enjoyment of Dutch language →number of m & s subjects chosen	-0.221	0
maths/science orientation →number of m & s subjects chosen	0.196	0.384
language orientation →number of m & s subjects chosen	-0.136	-0.261
parental education →number of m & s subjects chosen	0	0.218
IQ-score →number of m & s subjects chosen	0.013	0
child rearing style →number of m & s subjects chosen	0.239	0
extrinsic motivation of subject choice →number of m & s subjects chosen	-0.211	0.216
parental aspirations →number of m & s subjects chosen	0	0.099
maths/science orientation →maths score	2.832	0
IQ-score →maths score	0.214	0.288
parental education →maths score	1.272	0
maths/science orientation →enjoyment of maths	0.179	0.149
extrinsic motivation of subject choice →enjoyment of maths	-0.182	0
IQ-score →enjoyment of maths	0	0.012
language orientation → enjoyment of Dutch language	0.087	0
parental education → enjoyment of Dutch language	0.062	0
IQ-score → enjoyment of Dutch language	-0.007	0
IQ-score →maths/science orientation	0.006	0.006
parental education →maths/science orientation	0.052	0
parental education →parental aspirations	0	0.270
enjoyment of maths ↔ maths score	0	2.283
language orientation ↔ maths/science orientation	0.044	0.061

As can be seen from Table 3.4, there are three variables which only show up in one or the other causal model. The influence of family characteristics on the maths and science subject selection process is limited for the boys to child-rearing style. For the girls, only the parental aspirations play a role and then as a mediator of the influence of parental level of education. It can be further noted that Dutch language enjoyment is only of importance for boys. A higher level of parental education, lower intelligence and greater language orientation in year 1 can all be seen to contribute to Dutch language enjoyment in year 3 for boys. And to the extent that they report Dutch language enjoyment, they tend to choose fewer maths and science subjects.

Figure 3.3 also reveals some sex-specific relations. For girls, there are only indirect effects of IQ score; for boys, a direct effect is also apparent. A higher IQ score leads to greater maths enjoyment for only girls. Similarly, a significant correlation between maths enjoyment and maths achievement in year 3 is only observed for girls. And a significant relation between maths/science orientation in year 1 and maths achievement in year 3 is only found for boys.

Parental level of education influences the choice of maths and science subjects both directly and indirectly for girls and only indirectly for boys. Boys with higher educated parents are more maths/science oriented in year 1, attain higher maths scores in year 3 and also report greater Dutch language enjoyment than boys with lower educated parents. Via various interest-and achievement-related paths in both a positive and negative direction, parental level of education thus affects their choice of maths and science subjects.

Finally, one can speak of a direct effect of subject choice motivation in year 3 by both boys and girls although the polarity of the effect is sex specific. This was also observed in the multilevel analyses and explains why various conceptual paths involving this variable disappeared in the final causal model for all pupils. Subject choice motivation was also found to indirectly influence the number of maths and science subjects chosen via maths enjoyment but only for boys.

The order of importance for the direct effects on the choice of maths and science subjects also proved sex specific. Both sexes showed their choice of maths and science subjects to depend first and foremost on their maths enjoyment in year 3; boys however also consider just how good they are at maths at this point while maths/science orientation in year 1 plays a role for girls. In keeping with this, the effects of both language orientation and maths/science orientation on the number of maths and science subjects chosen are twice as strong for girls as for boys. Apparently girls choose more on the basis of interest, and achievement is less important for them when compared to boys.

3.6 Summary and discussion

The greater the number of maths and science subjects a pupil in Dutch pre-university education (i.e., VWO) chooses, the greater the number of possible future routes in tertiary Science, Technology, Engineering and Mathematics (or STEM) education available and thereby the pupil's chances of employment in the end. In the Netherlands, the take-up of maths and science subjects in upper secondary education is practically a *condition sine qua non* for the later STEM course choices in higher education. While in some other countries (e.g., Sweden; see also van Langen & Dekkers, 2005a, 2005b) for those who never chose these subjects, there are good opportunities to get back on the STEM track again at a later point, Dutch students who have made the wrong choices in upper secondary education find it very difficult

to recover lost ground. The number of maths and science subjects selected can thus be seen as an indicator of school success. And when groups of pupils distinguished according to sex and social and ethnic background but with otherwise equal capacities and achievement systematically differ with regard to their maths and science subject choice, one can speak of an inequality of educational opportunities. The research presented here examined this proposition with the aid of data from a large national cohort involving 987 VWO pupils in the Netherlands.
The results show that we can indeed speak of significant group-related differences with the most important difference pertaining to sex. Although since 1985 the Dutch government has set up various national campaigns to promote women's participation in science and maths education (see for instance Kabinetsnota, 2003), VWO girls (still) choose maths and science subjects to a much more limited extent than VWO boys – even when aptitude and maths achievement are controlled for. As a consequence, optimal use is not being made of the available Dutch science and maths talent.
Further analyses of the interaction effects with parental level of education and ethnic background show the choice of maths and science subjects by VWO girls to be influenced by these factors while the choice by VWO boys is not. Despite international reports of educational success for girls, very little has – in fact – changed over the past few decades with respect to their maths and science subject choice.

Which other pupil, family and school characteristics further influenced the observed differences was also examined. At the level of the school, a higher degree of urbanization for the community in which the VWO school is located related negatively to the number of maths and science subjects chosen. Given that this is a context characteristic, few policy conclusions can be derived from this finding. Second, girls at VWO schools where the grading committee played a role in the guidance of subject choice tended to choose fewer maths and science subjects than girls at other schools. One explanation for this is that possible weaknesses on the part of girls may be quickly interpreted in a sex-role reinforcing manner during such meetings.

The family characteristics found to have a limited effect were child-rearing style and parental aspirations for final child educational level. But the majority of the variables found to exert a significant effect on the choice of maths and science subjects typically concerned the pupil. An orientation towards maths and science and an orientation towards modern languages in the first year of secondary study and enjoyment of maths and enjoyment of the Dutch language in the third year were significant predictors. Also at the level of the pupil, an interaction between subject choice motivation and sex was found. Girls with extrinsic subject choice motives were more likely to choose maths and science subjects than girls with intrinsic subject choice motives. For boys, the opposite was found to hold but to a weaker extent. Behind this finding are sex differences in the amount of interest in and enjoyment of maths and science subjects: Only when girls ignore their inherent interests and enjoyment do they choose maths and science while boys who allow themselves to be guided by these to choose maths and science. An explanation for the declining choice of maths and science subjects by boys is thus also provided: Boys apparently consider subjects other than maths and science more important for their future.

The selected final examination package is the result of a long-term dynamic process. In order to gain greater insight into this, the manner in which the pupil and family characteristics found to be significant here influence each other was examined. By modelling the subject choice process for boys and girls separately, moreover, it was attempted to gain greater insight into the background to the large sex difference in the choice of maths and science subjects.

The modelling of the subject selection process resulted in causal models which only explain approximately one-third of the variance in the number of maths and science subjects. In such a manner, these models 'perform' worse than the final regression model from the first part of the present research (43%). Nevertheless, they provided greater insight into the subject choice process in general and the differences between boys and girls in particular. Our results confirm the importance of viewing subject selection as a chronological process which also proceeds differently for VWO boys than for VWO girls under the influence of different mediating variables.

Those variables which pertain to the orientation, interest and achievements of pupils stand central in the identified causal models. And three relations not previously hypothesized were found to stand out in particular: 1) to the extent that a boy or girl is more maths/science oriented, he or she also tends to be more language oriented; 2) Dutch language enjoyment is only relevant for the subject selection process of boys; and 3) maths achievement only relates to maths enjoyment for girls and only to maths/science orientation for boys.

Such stable pupil characteristics as sex, intelligence and parental level of education were positioned outside the central part of the model, just as the parental aspirations for final child educational level, child-rearing style and subject choice motivation. The core findings with regard to these characteristics can be summarized as follows.

- Boys are already more maths/science oriented in the first year of secondary study than girls. To the extent that a pupil is more maths/science oriented, he or she also tends to enjoy maths in year 3 and choose more maths and science subjects in the end.

- A pupil with a high IQ score in year 1 attains a high maths score in year 3 and will subsequently choose more maths and science subjects than a pupil with a low IQ score.
- Girls from a higher social class (indicated by the parental level of education) have parents with a higher level of educational aspirations for them, which leads to the choice of more maths and science subjects than by girls from a lower social class. Boys from a higher social class report greater Dutch language enjoyment but are also more maths/science oriented and attain better maths scores than boys from a lower social class.
- Boys are raised less autonomously than girls and, to the extent that a boy is raised more autonomously, he also chooses more maths and science subjects.
- As shown in the first part of our research: Boys who choose subjects for extrinsic reasons tend to choose fewer maths and science subjects while the reverse holds for girls.

The most striking conclusion on the basis of the final causal model for all VWO pupils is, that almost all the variance between boys and girls in the choice of science and maths subjects (93%) could be attributed to the direct relation between sex and the dependent variable. The causal model identified here does not, thus, provide an adequate explanation for why girls choose fewer maths and science subjects than boys. This disappointing finding can perhaps be partially explained by the absence of some variables within the models. The majority of the – according to the literature – relevant effects concern orientation, interest/enjoyment and achievement, and these were indeed included. There are nevertheless other characteristics which are influential, according to the literature, such as estimated competence, chances of success and effort, and recommendations from teachers, parents and so forth. The present database did not contain information on these variables. However, via the collection of supplemental data in an ongoing cohort study, we hope to attain a more complete picture of the sex-specific subject selection process in the future.

Notes Chapter 3

1. Along a scale of 2 to 6, the mothers of the selected pupils scored 4.03 (SD 1.035), the mothers of the non-selected pupils scored 4 16 (SD 1.087).

2. The variables at school level were omitted from further consideration because the software program Mplus (Muthén & Muthén, 2001) did not allow the hierarchical structure of a dataset to be taken into account in connection with a categorical outcome variable.

3. The measures of model fit were the root mean square error of approximation (RMSEA), the weighted root mean square residual (WRMR) and the p value for the chi-square test of model fit. The fit was found to be reasonably good with a RMSEA < 0.06, a WRMR < 0.90 and a p value > 0.05 (Muthén & Muthén, 2001, Appendix 5).

4. In Mplus, it is possible to specify and estimate (nondirectional) correlational connections between endogenous variables. All of the correlations specified by us – whether between exogenous or endogenous variables – are represented with a straight bi-directional arrow.

5. Given that an ordinal dependent variable is involved here, it is not possible to perform a so-called 'multi-sample' test to directly determine whether the models for the boys and the girls differ from each other. For this reason, a different course of action was undertaken and the model for the boys was simply applied to the data for the girls and vice versa.

4 Changes in mathematics and science choice following introduction of compulsory study profiles into Dutch secondary education*

4.1 Abstract

Since 1998, upper level secondary education pupils in the Netherlands are required to choose one of four study profiles with their own specific and fixed combinations of final examination subjects. With the aid of multilevel analyses, the extent to which this situation has led to changes in the determinants of mathematics and science choice (i.e., selection of a science profile) is examined for more than 3500 pupils from the national VOCL'99 cohort. From a meritocratic perspective, the relative contributions of various social-cultural background characteristics versus personal aptitude are examined. The introduction of the study profiles appears to have produced sharper lines with respect to social class and sex and optimal use is not made of the existing science talent.

4.2 Introduction

During the European Union (EU) top in Lisbon in 2000, the joint ministers agreed that the number of students completing a higher (i.e., post-secondary) education in a Science, Technology, Engineering or Mathematics (or STEM) field of study in 2010 should increase by some 15% and that the unequal distribution of men and women within this educational sector should be corrected (European Commission, 2002, 2004). The Dutch government is thus not alone in its struggle to promote interest in STEM courses (Kabinetsnota, 2003). The underlying problem in the Netherlands is larger than elsewhere, however, because participation in the STEM courses is considerably lower here than in most other EU countries which also holds for the participation of female pupils (van Langen & Dekkers, 2005a, 2005b).

Pupils successfully completing their final examinations in the two highest levels of Dutch secondary education (i.e., HAVO and VWO) can, in principle, pursue a higher, tertiary study. Whether they are admitted to a higher STEM course or not,

* A slightly different version of this chapter has been submitted for publication.

however, depends on their final examination subjects The choice of final examination subjects is made around the sixteenth year In the past, considerable research has been conducted on this future-determining moment of choice and the factors which influence the selection of mathematics and science subjects (for an international review, see van Langen, Rekers-Mombarg & Dekkers, 2004, forthcoming) In 1998, however, Dutch law was amended radically and upper level secondary education pupils were given less freedom to choose their own study subjects as a result of being required to choose from four fixed combinations of subjects (i e , the four study profiles) In this chapter, whether or not such background characteristics as sex and social class appear to exert less of an influence on the choice of maths and science subjects than before will be examined In order to do this, use will be made of the data from a large-scale national secondary school cohort, namely the VOCL'99 (i e , *Voortgezet Onderwijs Cohort Leerlingen* 1999)

4.3 Background to the research

In the Netherlands, upper level secondary school pupils choose their final examination subjects around the fourth year of study, which is at about the age of 16 Prior to 1998, pupils had considerable freedom of subject choice, which also implied major differences in the follow-up educational opportunities open to the pupils at times Particularly with the inclusion of chemistry, mathematics B (or pure mathematics) and physics in the set of final examination subjects, access to subsequent higher educational possibilities is expanded considerably That is, successful completion of the final examinations for the aforementioned maths and science subjects is often part of the admission criteria for higher institutes of education in the Netherlands

Recently, a study of the determinants of maths and science choice was conducted among a cohort of pupils who still had the freedom of subject choice referred to above (i e , a VOCL'93 cohort) (van Langen et al , 2004, forthcoming) Given equal levels of achievement, the results showed HAVO girls and HAVO pupils with low educated parents to choose fewer maths and science subjects than HAVO boys and HAVO pupils with high educated parents, respectively For the VWO pupils, interactions occurred in the sense that the number of maths and science subjects chosen by boys was not influenced by their ethnic or social background while the number of maths and science subjects chosen by girls were native Dutch VWO girls with high educated parents tended to choose just as many maths and science subjects as VWO boys in general while native Dutch VWO girls with low educated parents rarely chose maths and science subjects Non-native VWO girls were found to choose more maths and science subjects to the extent that their parents were lower educated In the same study, whether or not a number of other pupil, family and school variables influenced the choice of maths and science subjects – after control for achievement and other background characteristics – was also examined The following factors were found to exert a positive – unless otherwise mentioned – influence

- at the level of the pupil, orientation towards maths and science subjects in the first year of secondary study, orientation towards modern languages in the first year of secondary study (negative), enjoyment of maths in the third year, enjoyment of Dutch language in the third year for only VWO pupils (negative), and subject choice motivation in the third year of study in interaction with sex – that is, girls with an extrinsic subject choice motivation (e g , 'I choose those subjects which will be useful for later') selected more maths and science subjects than girls with an intrinsic subject choice motivation (e g , 'I choose those subjects which I like or am good at') while boys with an extrinsic subject choice motivation chose fewer maths and science subjects than when their motivation was intrinsic
- at the level of the family, the extent to which autonomy is granted to the child as part of the child-rearing style and, for only VWO pupils, the parental level of educational aspiration for the child,
- at the level of the school, the degree of urbanization characteristic of the community in which the school is located (negative) and the involvement of the grading committee in advising with respect to the subject choices of only VWO girls (negative)

In 1998, a radical amendment to the law in the Netherlands was introduced, and freedom to mostly choose one's own secondary school subjects became a thing of the past Upper level pupils are now required to choose from four cohesive secondary education curricula which each have their own specific and fixed combination of subjects The pupils thus take a number of generally mandatory subjects such as Dutch and English, the subjects specific to the profile which they have chosen, and a few elective subjects The introduction of the profiles is intended to make pupils more aware of their study options and professional possibilities, on the one hand, and establish greater educational cohesion to better prepare pupils for their subsequent education The four profiles are culture & society, economics & society, science & health and science & technology In the two science profiles, chemistry, maths B and physics are mandatory, however, only certain parts of the chemistry, maths B and physics curricula are mandatory for the science & health profile while the complete chemistry, maths B and physics curricula are mandatory for the science & technology profile[1] In the science & health profile, the entire biology curriculum is also mandatory as this profile was specially designed to prepare pupils for a career in health care or the environment Only the science & technology profile was initially designed to prepare pupils for a subsequent STEM course but, in light of recent educational and employment shortages, adjustments have been made and pupils with the science & health profile are also now given direct access to most STEM courses Some 20% of those pupils graduating with a

science & health profile have indeed been found to select a higher STEM course while some 66% of the pupils graduating with a science & technology profile have been found to do so (Inspectie van het Onderwijs, 2005)[2]
For admission to many of the other non-STEM higher education studies, either a HAVO diploma or a VWO diploma – irrespective of the specific study profile – is generally sufficient. This means that the two science profiles provide a greater number of higher education admission possibilities than the two society profiles. And in this sense, the situation in the Netherlands now is comparable to the situation before 1998 when the number of follow-up perspectives increased with the number of maths and science subjects studied[3]

4.4 Theoretical framework and research problem

The systematic underrepresentation of specific groups of pupils according to sex and social or ethnic background in maths and science education, as discerned in the previously mentioned study by van Langen et al. (2004, forthcoming), can also lead to unequal opportunities for higher education and employment. From a meritocratic perspective, educational selection should only occur on the basis of the personal accomplishments of pupils and not be associated with sex or social group (Dekkers & Bosker, 2004). The associations between sex, parental level of education and ethnic origin, on the one hand, and maths and science subject choice, on the other hand, thus constitute evidence for the reproductive, non-meritocratic character of Dutch secondary education.

The cohort on which the aforementioned study was conducted involved pupils who were not confronted with the mandatory choice of a study profile. The question which then arises thus concerns the extent to which the preceding findings also hold for the new situation. The mandatory selection of one of four study profiles was introduced to help pupils gain insight into their aptitudes and possibilities in a timely fashion. The Educational Inspectorate also claims that the measure has worked and that pupils indeed choose differently than before. 'Schools report a more conscious subject selection process on the part of pupils' (2003, p. 19). In such a manner, it is also suggested that the individual capacities of pupils exert a greater influence on the choice of subjects than before, presumably at the cost of such background characteristics as sex and social or ethnic background.

In the present study, the above claim will be explored in greater detail. The associations between the personal capacities of pupils in the upper levels of secondary education, on the one hand, and the background characteristics of these pupils, on the other hand, as an explanation for the choice of a science profile will be examined. In doing this, we will also keep in mind that the relevant concepts may be understood differently at times The structural background characteristics to be examined in any case are sex, social class and ethnic origin, but these can certainly be supplemented with such related cultural background variables as social and cultural capital With regard to aptitude and the personal accomplishments of pupils, achievement is of obvious importance When aptitude is construed more broadly, attitudinal characteristics such as interest and effort may also become relevant (Meijnen, 2004) The extent to which such attitudinal characteristics should be understood as purely related to aptitude or also amenable to the influences of various social and cultural factors is very much open to debate, however Dekkers and Bosker (2004) assume that certain attitudinal characteristics are more disposition related and thus innate while others are more the product of socialization The greater the influence of the latter with respect to study choice, however, the lower the meritocratic calibre of Dutch education

The above opposition can also be applied to the explanations at the level of the pupil and his or her parents and peers, which are put forth in the literature for the educational choice differences described elsewhere in extensive detail (van Langen et al , 2004, forthcoming) Summarized briefly Individual pupils rationally choose between alternatives on the basis of interest, attributed utility and expectations of success, which are influenced by subjective perceptions, interpretations and attributions of actual experiences and the socializing influences of parents and other individuals within the environment of the pupil (e g , Dryler, 1998, Elsworth, Harvey-Beavis, Ainley & Fabris, 1999, Jonsson, 1999, Zeldin & Pajares, 2000, Marjoribanks, 2002, Ainley & Elsworth, 2003, Uerz, Dekkers & Beguin, 2003, van der Werfhorst, Sullivan & Cheung, 2003) The aforementioned factors thus consist of a mixture of personal capacities reflecting a more meritocratic calibre of education and variables related to the sex or social group of the pupil with a more reproductive function

Studies of school effectiveness also show schools to clearly differ with respect to the extent to which their pupils choose maths and science subjects (Bosker & Dekkers, 1994) The explanations offered for this variation include, among other things, the influence of such previously mentioned contextual school characteristics as the degree of urbanization for the community in which the school is located (van Langen et al , 2004, forthcoming), the average level of pupil achievement or report marks (Dryler, 1999) and the composition of the school population in terms of sex and social class (Smyth & Hannan, 2004) A different category of explanations concerns the organizational characteristics of the schools including the manner in which the advising with regard to subject choice is arranged (Roger & Duffield, 2000, Leenders & Stokking, 2001) Finally, the observed differences in subject choice across schools may also be the result of specific stimulation measures or projects (Educational Inspectorate, 2004, 2005) An example of this is the offering of a combined chemistry and physics course in order to expand the relevance of the two subjects and the connections between them (Bell, 2001; Colley & Comber, 2003).

From the perspective of meritocracy, the question is predominantly whether the explanatory school characteristics reinforce or neutralize the reproductive effects of social and cultural background factors. If they are found to neutralize the effects of such, then they clearly speak in favour of the meritocratic calibre of education.

In the first part of this study, we will limit ourselves to an examination of the relative contributions of the structural background characteristics versus pupil capacities to the explanation of the choice of a science profile. Thereafter, we will examine which other factors at the levels of the pupil, family and school appear to influence the choice of a science profile and the extent to which the influence of such provide additional evidence for the meritocratic versus reproductive calibre of Dutch education today. The specific research questions underlying the present study are thus as follows.

1. How do the contributions of sex and social or ethnic background versus achievement to the choice of a science profile relate to each other since the introduction of the study profiles?
2. What other factors at the levels of the pupil, family and school appear to influence the choice of a science profile?

4.5 Method

4.5.1 Data collection

In this research, use is made of the data from the national VOCL'99 cohort involving pupils who are in their first year of secondary school in 1999/2000. The cohort encompassed all levels of secondary education in the Netherlands and included, at the start, some 20,000 pupils from 126 institutes for secondary education which were largely representative of the national population of pupils and schools (Kuyper & van der Werf, 2003).

Intake figures with regard to the pupils were collected from the school administrations during the first cohort year. Thereafter, information on the level of secondary education being followed and the year of study for the cohort pupils was requested on an annual basis. In the 2003/2004 academic year, which was the fifth cohort year, the annual collection of the data on the cohort pupils was expanded to include the choice of study profile by those pupils in a higher level of secondary education (i.e., HAVO or VWO).

In addition to the above, tests of Dutch language, maths and information-processing skills were administered to the pupils during the first cohort year and, in addition, both the pupils and their parents were asked to complete a written questionnaire In 2001/2002, those pupils in their third year of secondary school were again administered Dutch language and maths tests and again asked to complete a written questionnaire Due to the limited willingness of many schools to continue participating in the study and – to a much lesser extent – the dropout of pupils[4], the response rate was only 56% for the tests and 50% for the questionnaires administered in the third year of secondary school

Specifically for the present study, an extra questionnaire for the higher level (i e , HAVO and VWO) pupils was added to the VOCL pupil questionnaire for administration in the third year of secondary school The response rate for this questionnaire thus resembles the response rate for the VOCL questionnaire All of the cohort schools providing a higher level of secondary education were also sent an extra questionnaire in 2002/2003 for completion by the directorate or guidance counsellor The response rate for this questionnaire was 78%

The explanations for the differences in the choice of maths and science subjects put forth in the relevant research literature were operationalized in the questionnaires via questions regarding pupil evaluations and expectations with respect to certain subjects and teachers, recent report marks, school and parent recommendations, the educational ambitions of both the pupil and his or her parents, interest in different disciplines for follow-up study and the attractiveness of different career aspects The school questionnaire addressed primarily the organizational characteristics of profile choice, which included the manner of advising with respect to study choice in general and any specific measures undertaken to explicitly stimulate the choice of a science profile in particular Special attention was also paid to the offering of a combined chemistry and physics course as a single subject, and to the phasing of the choice of study profile Some schools in the Netherlands first require selection of a so-called stream (i e , general science or general society curriculum) and then, some time later, the specific profile And there are indications that a science profile is chosen more often in these schools than in other schools (PMVO, 1999)

4.5.2 Description of the database

Of the approximately 20,000 pupils from the VOCL'99 starting cohort, 7781 were in the upper levels of secondary education (i e , HAVO or VWO) in the fifth cohort year Out of this group, only those pupils for which the test results and results of the two pupil questionnaires administered in the third year of secondary school were available and for which the choice of profile was known were selected for inclusion

in the database. The final research group included 1648 HAVO pupils and 1965 VWO pupils from 52 schools[5]. The representativeness of the database was checked by comparison of a number of the characteristics of the 3513 selected pupils to the characteristics of the 4268 non-selected pupils. The research group was found to deviate with a significantly higher percentage of VWO pupils (47% vs. 38%) and native Dutch pupils (87% vs. 82%). Divided according to the level of secondary education (i.e., HAVO or VWO), the selected HAVO pupils were significantly more often female than the non-selected HAVO pupils (54% vs. 50%, respectively). The former also achieved significantly better than the latter, as indicated by a number of achievement measures[6]. While no significant differences were detected in the general test scores for the VWO pupils selected for inclusion in the research group versus not, the English and maths report marks in the first year of secondary school were somewhat higher for the former group than for the latter group[7]. Compared to the group of non-selected pupils, thus, the research group was somewhat better achieving. In light of the size of the sample and the nature of the research question, however, these slight differences in achievement should have very few consequences for the validity of the research results. Significant differences in the study profiles being considered in the first year of secondary school by the selected versus non-selected pupils were also not detected.
The non-selected pupils were almost all in schools where the questionnaire administered to the school directorate as part of the VOCL during the second cohort year was not completed and the school characteristics for the two groups of pupils therefore cannot be compared. On the basis of this, it can – however – be concluded that VOCL dropout and thus the dropout in the present study is predominantly a consequence of non-response on the part of the schools and not pupils (also see note 4).

4.5.3 Description of the variables

Dependent variable

The aim of the present study was to identify the determinants of the choice of a science profile by pupils in the highest levels of secondary education. As indicated in the Introduction, the science & technology profile and science & health profile are not completely comparable. While successful completion of the final examinations for one or the other of the profiles provides direct access to a subsequent STEM degree course, the chances of a pupil actually progressing to such a course are much larger for the science & technology profile than for the science & health profile. Substantive differences in the amounts of maths and science provided by the two profiles also clearly exist. Whereas only certain components of the maths and science subject curricula are required for the science & health profile, the complete maths and science subject curricula are required for the science & technology profile For this reason, an ordinal variable was constructed to represent the degree of maths and science in the study profiles and serve as the dependent variable in our analyses A value of 0 represents the society profiles, a value of 1 represents the science & health profile, and a value of 2 represents the science & technology profile[8]

Background characteristics

Four variables were selected to serve as (structural) background variables sex, the highest level of education for the family – irrespective of whether this is for the mother or father – as an indicator of social class, level of education for the mother, and ethnic origin determined on the basis of country of birth for the pupil and both parents A more detailed description of these variables can be found in Kuyper, Lubbers and van der Werf (2003)

Achievement

The actual achievement of the pupils prior to the choice of study profile was represented by nine variables coming from the different measurement years Collected during the first year of secondary school but actually measured during the last year of primary school are the National Institute for Educational Measurement achievement scores The so-called 'CITO' is a method-independent set of tests administered by about 90% of the primary schools in the Netherlands during the last of year of primary school From the first year of secondary school, the VOCL cohort test scores for Dutch language, maths and information-processing skills were used (Kuyper et al , 2003) From the third year, the scores attained on maths tests, Dutch language tests and general skills tests were used (Kuyper & van der Werf, 2005) Finally, two additional variables which are not really achievement measures but closely related to achievement were also included the level of secondary education recommended by the primary school and the actual level of secondary education being followed in the fifth year of secondary school (i e , HAVO or VWO)

Other potentially explanatory variables

On the basis of the relevant research literature, many other possibly explanatory variables were selected from the database for the present analyses To reduce the number of variables, exploratory analyses were conducted in which the rough associations of all the variables to the dependent variable (see above) were tested[9] A few of the characteristics which were found in previous research to significantly affect the choice of maths and science subjects (see section Background to the research) were found to be among the variables which did not weather the tests of significance conducted here degree of urbanization for the community in which the school is located, involvement of the grading committee in advising with respect to subject choice and parental style of child rearing.

The reduced set of potentially explanatory variables was still quite extensive, which means that the variables will be discussed in groups below. In the notes accompanying this chapter, more specific information is presented with respect to the values which the variables could have, reliability outcomes and so forth. Additional information can also be found in the VOCL'99 reports (Kuyper & van der Werf, 2003, 2005, Kuyper et al., 2003).

1) Pupil evaluations of subjects and teachers[10]

From the pupil questionnaire administered in the third year of secondary school, the opinions of the pupils with regard to the subjects and the teachers of Dutch language and maths were selected for analysis.
In the same pupil questionnaire, inquiries were also made about the importance for the pupil of the 20 different subjects offered during that year. The responses concerned with the three foreign languages of English, French and German and the three maths and science subjects of chemistry, mathematics and physics were selected for further analysis.
In addition, a number of propositions regarding the specific subjects and teachers of physics, French and economics were presented to the pupils in the third year of secondary school for evaluation. This led to the creation of a series of scales reflecting the pupil's estimated subject competence, subject enjoyment, perceptions of the utility of the subject for his or her future, perceptions of the general utility of the subject, pupil's opinion of own subject competence from the perspective of the teacher, enjoyment of the lessons taught by the teacher, judgements of the extent to which the teacher paid attention to the social relevance of the subject and judgements of the extent to which the teacher made the pupils work particularly hard during the lessons.

2) Report marks[11]

In the third year of secondary school and to a more limited extent in the first year, the most recent report marks were requested. The report marks for maths and English in the first year and the average report marks for the modern foreign languages in the third year and the maths and science subjects in the third year were then selected for inclusion in our analyses.

3) Advising and suitability of such according to third parties[12]

In the third year of secondary school, information on the study recommendations of the school and parents regarding the four profiles was requested. The pupils were also asked to estimate whether the school and parents considered the subjects of physics, economics and French to be suitable final examination subjects for them. On the basis of this information, 14 variables were then selected for inclusion in our analyses.

4) Future plans/ambitions of pupils and parents[13]

Three variables were selected from the first year pupil questionnaire: the choice of study profile expected; intrinsic versus extrinsic motivation for the expected choice of profile; and level of educational aspirations. From the parent questionnaire administered in the same year, the parental level of educational aspiration for their child was also selected for analysis.
For the third year of secondary school, a variable concerned with the number of days per week which pupils later want to work outside the home and similarly when they have children was selected for analysis. Various career characteristics were also presented to the pupils in the third year of secondary school with the request that they indicate the extent to which they apply to the profession which they would later like to practice. The responses were found to constitute six scales: profession with high status; social profession; science/technical profession; art/media profession; outdoors profession; and profession with limited responsibilities. Similarly, the interest of the pupil in a variety of educational disciplines was probed and found to result in the following scales: health/social care; management/business; science/technology; education/media; and agriculture/environment.
One variable which does not fit perfectly into this category (or any other category, for that matter) is that indicating whether the parents have a technical profession or not. This was assessed when the pupils were in the third year of secondary school.

5) Learning style[14]

In both the first and third years of secondary school, the pupils were asked to estimate how much time they spent, on average, on homework for all subjects considered together per day and for maths, on average, per week. The same questionnaires contained a question which addressed study behaviour more specifically. The responses to this question formed three scales reflecting different learning strategies: an 'integrative' strategy, a 'concrete' strategy and an 'extra work' strategy (Kuyper et al., 2003). Homework behaviour during the first and third years and learning strategy during the third year were selected for inclusion in our analyses.

6) School organization characteristics[15]

This group of characteristics is substantively less cohesive than the preceding groups and based on the school questionnaire administered in 2002/2003. The variables indicate the involvement of the guidance counsellor and the individual teachers in the advising and guidance of the pupil choice of study profile, the more or less steering character of the school recommendation with regard to study profile, the points and principles which play a role in the decision-making of the school with regard to study profile, specific measures possibly undertaken to promote the choice of science profiles and the combined teaching of chemistry and physics as a single subject.

7) Contextual school characteristics

The final group of characteristics concerns the school averages for a number of the previously mentioned pupil characteristics. Stated concretely: the parental level of education for the school on average, the percentage of boys in the school, the average score for the school on the maths test administered in the first year of secondary school, the school average for the three maths and science report marks in the third year, the average pupil evaluations of the subjects and teachers of maths and physics in the third year of secondary school and, finally, the average school recommendation regarding the two science profiles in the third year.

4.5.4 Design of the data analysis

In order to accurately map the interrelations between the variables at the levels of the pupil, parents and school, multivariate analyses were conducted. The pupils in the highest levels of secondary education (i.e., HAVO and VWO) were analyzed together in order to obtain the largest research group possible. The underlying assumption that the two groups of pupils would show similar results was nevertheless checked (see below).
With the use of multilevel analyses, justice is done to the hierarchical structure of the data with pupils grouped within schools. Given the level of measurement for the dependent variable (see above), the multilevel analyses are based on an ordered multicategorical response model (Goldstein, 1995; see also Appendix A).

The procedure for the multilevel analyses involves a number of steps. First, the effects of the background variables for the pupil on the degree of maths and science in the chosen study profile (i.e., the number of maths and science subjects and depth/breadth of such; see also description of Dependent variable above) and whether one can speak of an interaction between the different variables is examined.

Only those background characteristics and interactions which are significant at an α<0 05 are retained The model containing only the significant background characteristics and significant interactions is next expanded to include characteristics reflecting pupil achievement Once again, only those characteristics which are significant at an α<0 05 are retained When the variables as actually measured in this first model are replaced with standardized variables[16] and the model is again fitted, insight can be gained into the relative weight of the observed predictors

In the next step in the analyses, the preceding model – with only significant nonstandardized background characteristics and achievement measures included in it – is expanded with each of the seven groups of other possibly explanatory variables described in the previous section For each group of variables, only those which are significant are retained A 'backwards' selection procedure is used to do this with an α<0 001 for variables measured at the level of the pupil (variable groups 1 through 5) and an α<0 01 for variables measured at the level of the school (variable groups 6 and 7) The strict selection criteria are intended to prevent this step in the analyses from becoming too much of a 'fishing expedition' and producing a number of significant predictors simply by capitalizing on chance

Finally, all of the variables which survived the tests of association with the dependent variable are simultaneously entered into the model containing only the significant background characteristics and pupil achievement measures Those variables which no longer show a significant association with the dependent variable are then removed from the model (α<0 001 for the pupil variables and α<0 01 for the school variables) The resulting model is referred to as the final general model and provides a good picture of which pupil, family and school characteristics are predictive of the degree of maths and science in the study profiles chosen by pupils in the upper levels of secondary education Once again, the relative weight of the detected predictors is determined by replacing the variables as actually measured by standardized variables and fitting the model again

In order to determine the extent to which the determinants of the choice of a science profile differ for boys versus girls, the preceding steps are repeated but then separately according to sex Any significant findings can then be added to the final model in the form of an interaction term with sex Possible differences between pupils in the different levels of secondary education (i e , HAVO versus VWO) are similarly examined and the relevant interaction terms involving the level of secondary education added to the final model

4.6 Results

4.6.1 The relative influences of background characteristics versus achievement

Of the 3513 pupils in the sample, almost 63% chose a society profile, more than 21% chose a science & health profile, and 16% chose a science & technology profile For the first, so-called empty model tested in the multilevel analyses (i e , a model containing no explanatory variables whatsoever), the estimated distribution of pupils corresponded closely to the actual distribution

As explained in the preceding section, all four background variables including the relevant interaction terms were first added to the empty model and then the nine achievement measures including the relevant interaction terms A summary of the standardized results is presented in Table 4 1 where only the significant effects are presented to prevent an excess of numbers Some 23 8% of the total variance in the dependent variable is explained by Model 1 (see also Appendix A)

Table 4 1 – Results for Model 1, all variables have been standardized

	Variables	Estimates	SE
Background	Sex=boy	0 450	0 038***
	Highest education for family	0 115	0 039**
Achievement	Language score year 1	-0 117	0 042**
	Maths score year 1	0 286	0 047***
	Maths score year 3	0 637	0 048***
	Level of secondary education year 5=VWO	0 127	0 042**
	Variance at level of school	0 129	0 042**

** sign p<0 01, *** sign p<0 001

Of the four background characteristics, the variables sex and highest level of education for the family both exert an independently significant effect upon the dependent variable This does not hold for the variable of ethnic origin and, after addition of the highest level of education for the family, maternal level of education also does not make an extra contribution Of the nine achievement measures, four were significant the Dutch language score (negative) and maths score in the first year of secondary school, the maths score in the third year, and the level of secondary education actually being followed in the fifth year None of the interaction terms were significant

Given that all of the variables in the table are standardized, including the dichotomous variables, it is possible to directly compare the relative contributions of the detected predictors. We can conclude that the degree of maths and science in the chosen study profile was most strongly predicted by the maths scores attained in the third year of secondary school followed by sex and the maths scores in the first year of secondary school. The three remaining variables made more or less equal contributions: level of education in the fifth year, Dutch language scores in the first year and the highest level of education for the family. With this, an answer to our first research question is also attained. The achievement measures – which refer to aptitude and the personal accomplishments of the pupil – considered together contribute most to the variance explained in the degree of maths and science in the chosen study profile, which is in keeping with the meritocratic ideal. The influence of sex should not be trivialized, however, just as the influence of parental level of education which was relatively limited but nevertheless significant and independent. The relevance of these two background variables is further apparent when the 18.9% of the variance explained by the model containing only the significant achievement measures is compared to the 23.8% of the variance explained by the model containing both the significant achievement measures and the significant background variables of sex and parental level of education. The difference of 4.9% is exclusively explained by sex and parental level of education.

The preceding thus shows the choice of a science profile to still be determined in part by non-meritocratic, background characteristics of the pupil in addition to personal aptitude. Given equal levels of test achievement and involvement in the same level of secondary education, boys and the children of high educated parents tend to have a higher degree of maths and science in the study profile than girls and the children of low educated parents, respectively.

When the implications of the above for actual practice are considered, the extremely low percentage of girls in our sample choosing a science & technology profile stands out in particular: at the level of HAVO, slightly more than 1% of all the girls, at the level of VWO, almost 7%. For comparison: at the level of HAVO, some 25% of the boys in our sample chose the science & technology profile; at the level of VWO, as much as 36%. The effect of a higher level of parental education for most girls is thus that they opt for a science & health profile as opposed to a society profile at most. Next, the extent to which the maths scores and average report marks for the maths and science subjects in the third year of secondary school for girls in a science & health profile possibly deviate from the scores and marks for boys in a science & technology profile was examined. The numbers show the averages for the two groups to differ significantly although the achievement ranges for the two groups overlap considerably[17]. Many of the girls in a science & health profile thus achieved equally in the third year of secondary school to the boys in a science & technology profile.

4.6.2 Other determinants at the levels of the pupil, parents and school

In order to identify other determinants of the selection of a science profile by secondary school pupils, the seven different groups of potentially explanatory variables were first added separately and, for those which were found to be significant, then simultaneously to Model 1 (see Design of the Data Analysis section). This resulted in the final general model. The standardized version of this model is presented in Table 2. Some 77.5% of the total variance in the dependent variable is explained by this model (see also Appendix A). Only the significantly explanatory pupil and school variables, ordered according to the size of their contribution, are included in this table[18]. In Appendix C, some supplemental information with regard to the variables is presented (Table C.1).

Inspection of Table 4.2 shows a number of the achievement measures to no longer be significant, namely: the Dutch language and maths test scores from the first year and the level of secondary education being followed in the fifth year. The analyses were nevertheless designed to control for the relevant background characteristics and achievement measures from Model 1 during each analytic step, and the inclusion of the no longer significant achievement measures in the final model scarcely influences the resulting coefficients when compared to non-inclusion.

For six of the seven groups of other potentially explanatory variables (see Description of the Variables section), at least one variable occurred in the final model. Not one single variable from the group of 'Contextual school characteristics' was included.

A number of the variables from the first group which measured 'Pupil evaluations of subjects and teachers' significantly influenced the degree of maths and science in the chosen study profile after control for achievement measures, sex and the highest level of education for the family. Perceptions of the utility of physics for the pupil's own future was found to make the largest contribution by far. Thereafter, the reported importance of the maths and science subjects for the pupil and, slightly lower in the table, enjoyment of maths in particular. Two other variables from this same group made almost equal contributions: the extent to which the pupil thinks that the teacher of economics considers the pupil him/herself to be competent in that subject and the judged importance of the three foreign languages for the pupil. Both variables exerted a negative effect on the degree of maths and science in the chosen study profile.

Table 4.2 – Results for final general model; all variables have been standardized

Background and achievement	Estimates	SE
Sex=boy	0.204	0.062***
Highest education for family	0.141	0.050**
Language score year 1	-0.037	0.056
Maths score year 1	0.099	0.062
Maths score year3	0.259	0.063***
Level of secondary education year 5=VWO	-0.016	0.058
Other determinants at level of pupil		
Utility of physics for own future	1.227	0.076***
Importance of maths and science subjects	0.561	0.078***
Report marks maths and science year 3	0.476	0.066***
Maths enjoyment	0.455	0.064***
Parental recommendations regarding economics & society profile	-0.356	0.057***
Parental recommendations regarding science & technology profile	0.332	0.071***
Pupil competent according to economics teacher	-0.296	0.052***
Importance of modern foreign languages	-0.288	0.054***
Science/technical profession desired	0.283	0.062***
School recommendations regarding science & technology profile	0.274	0.072***
Physics considered suitable final examination subject by parents	0.272	0.070***
Use of concrete learning strategy	-0.189	0 054***
Other determinants at level of school		
School policy for profile choice (ref.= 'As little steering as possible'):		
- 'Stimulate selection of science profile as much as possible'	0.312	0 076***
- 'Even distribution across 4 profiles'	0.179	0.063**
- 'Science profile for only those who can handle it'	0.108	0.073
- Unknown	0.228	0.071**
Importance of choosing profile with most follow-up possibilities	-0.277	0.074***

** sign. p<0.01; *** sign. p<0.001

One variable from the second group of variables pertaining to 'Report marks' exerted a significant effect, namely the average report mark for the three maths and science subjects in the third year of secondary school. The contribution of this variable was comparable to that for pupil enjoyment of maths.

A total of four variables from the third group labelled 'Advising and suitability of such according to third parties' contributed to the degree of maths and science in the chosen study profile. Three of the four variables concerned the parents. The recommendations of the parents with regard to an economics & society profile and a science & technology profile made opposite but very comparable contributions, with the former exerting a negative effect and the latter exerting a positive effect on the degree of maths and science in the chosen study profile. The recommendations of the school with respect to the choice of a science & technology profile by the pupil occurs lower in the table along with the extent to which the parents consider physics to be a suitable final examination subject for the pupil

One variable from the fourth group addressing 'Future plans/ambitions of the pupils and parents' contributed significantly to the degree of maths and science in the chosen study profile namely, the desire for a later science/technological profession With regard to the weight of the contribution made, this variable occurs between the judged importance of the three foreign languages and the school recommendation with respect to the pursuit of a science & technology profile

The smallest significant contribution at the level of the pupil is made by a variable coming from the fifth group of variables concerned with 'Learning style ' To the extent that a concrete learning strategy is employed, a science profile is less often chosen

Those variables found to be significant at the level of the school, both come from the sixth group concerned with 'School organization characteristics' collected via the school questionnaire administered to the school directorate or guidance counsellor The first variable concerns the school policy with regard to the choice of study profile The majority of the respondents (75%) indicated that the policy of the school was to steer the choice of a study profile as little as possible In those schools which deviated from this, a study profile with a higher degree of maths and science was chosen more often This particularly holds for the few schools where efforts were explicitly made to have as many pupils choose a science profile as possible The influence of the aforementioned school policy variable is comparable to that of the recommendations of the parents with regard to a science & technology profile The second significant variable at the level of the school operates in an unexpected direction Pupils appear to choose a higher degree of maths and science in the study profile more frequently when the school – in the opinion of the respondent – attaches less importance to the choice of a study profile with the most follow-up possibilities The contribution of this variable is roughly comparable to the contribution of the recommendations of the school with respect to the choice of a science & technology profile by the pupil

In light of the unexpected direction of the influence of the second school-level variable mentioned above, the correlation between the two significant school-level variables was examined The nature of the association was just as expected Schools which strive to have as many pupils pursue a science profile as possible also attach considerable importance to selection of the study profile with the most follow-up possibilities Whether or not one can speak of multicolinearity between the two variables was next examined and found to not be the case

In the initial empty model and also in the models with only pupil-level variables entered as predictors, the variance at the level of the school was found to be significant. Of all the school-level variables subsequently entered as predictors, only the two aforementioned variables were found to make a significant contribution. The contribution of these variables was nevertheless such that the variance at the level of the school was no longer significant in the final model.

The original significance of the between-school variance shows the schools in our research to clearly differ with respect to the extent to which their pupils opt for a higher degree of maths and science in the chosen study profile. For illustrative purposes, the extent to which the schools at the two ends of the spectrum differed from each other was calculated. The schools in our research sample were first sorted according to their average scores on the dependent variable. Those two schools falling in the 10th and 90th percentiles were then selected for further examination. The 10th percentile school had a total of 64 pupils in the upper levels of secondary education (i.e., HAVO and VWO) and 80% of the pupils chose a society profile, 13% a science & health profile and 8% a science & technology profile. The 90th percentile school had a total of 106 pupils in the upper levels of secondary education and 50% chose a society profile, 28% a science & health profile and 22% a science & technology profile.

4.6.3 Interactions with sex and level of secondary education

In order to determine whether we can speak of sex differences in the determinants of the degree of maths and science in the chosen study profile, the preceding analyses were again conducted but separately for boys and girls. The results showed most of the variables from the final model to be of about equal importance for the boys and girls. A few of the variables nevertheless exerted their influence according to sex. This holds, to start with, for the desire to pursue a science/technical profession; the significant effect of this variable stems almost entirely from the boys in our sample (nonstandardized estimate of 0.58) and is virtually absent for the girls (0.06). The negative effect of pupil judgements of the importance of the three foreign languages for themselves was also three times as strong for the boys (-0.85) as for the girls (-0.27). The estimated utility of physics for the pupil's own future also exerted a larger effect for the boys (1.81) than for the girls (1.27). Finally, the sex-specific findings revealed a variable which was not included in the final general model due to the opposite directions of the effect for boys versus girls: the recommendations of the parents with regard to the choice of a science & health profile. For girls, a more positive recommendation from the parents led to a higher degree of maths and science in the chosen study profile (nonstandardized estimate of 0.35) while the opposite held for boys (-0.16). This finding suggests that, when parents recommend a science & health profile, girls may shift their choice from a society profile to a science & health profile and boys from a science & technology profile to a science & health profile.

Whether or not differences also existed in the determinants of the degree of maths and science in the chosen study profile for the pupils in the different levels of upper secondary education (i.e., HAVO vs. VWO) was also examined. Pupils who think that the teacher of economics considers them competent in that subject tended to choose a lower degree of maths and science in the study profile, but this effect was accounted for by primarily the HAVO pupils (nonstandardized estimate of -0.83) and less by the VWO pupils (-0.30). The other effects in the final general model did not differ for the two levels of secondary education.

When the aforementioned interactions with sex and level of secondary education are added to the final general model, a small increase to 78.1% in the amount of variance explained is observed.

4.7 Conclusions

The purpose of this study was to identify which determinants appear to be decisive for the choice of a science profile. More specifically, we wanted to identify the relative contributions of socio-cultural background characteristics and personal aptitude to this choice. For this purpose, the data on 3513 pupils in the upper levels of secondary education (i.e., HAVO or VWO) from the national VOCL'99 cohort were analyzed.

The research problem and design of the study were divided into two parts. The results of the first phase in the analyses showed the test scores in the first and third years of secondary school and the level of secondary education being followed in the fifth year (i.e., HAVO, VWO) to make the largest relative contributions to the degree of maths and science in the chosen study profile. This is in keeping with the meritocratic educational ideal in which the personal capacities of the individual pupil determine school career and school success. After control for test scores and the level of secondary education, however, sex and the parental level of education (i.e., the highest level of education for the family) significantly influenced the degree of maths and science in the study profile which was chosen: boys and the children of high educated parents tended to choose a higher degree of maths and science in the study profile than girls and the children of low educated parents, respectively. An effect of parental level of education is even observed for the highest level, VWO, boys while the number of maths and science subjects chosen by such boys did not generally vary depending on the parental level of education prior to the introduction of the study profiles (van Langen et al., 2004, forthcoming). A very small percentage of the girls was found to select a science & technology profile, and this was found to hold for the HAVO girls in particular. Slightly more than 1% of the HAVO girls opted for a science & technology profile irrespective of the parental level of education while, prior to 1998, about 9% of the HAVO girls included the subjects of chemistry, mathematics B and physics in their studies. For the VWO girls, less than 7% chose the science & technology profile while, prior to the introduction of the study profiles, about 30% included chemistry, mathematics B and physics in their studies[19].

The introduction of the study profiles for the upper levels of secondary education has thus produced, at least in part, sharper distinctions along the lines of social class and sex. This shows Dutch secondary education to still have a reproductive component, even within the relatively homogeneous HAVO and VWO levels of secondary education. The science & technology profile appears to be almost exclusively the domain of boys with an overrepresentation of the children of high educated parents among the group of pupils who select such a science & technology profile. The maths achievement and report marks in the third year of secondary school for a considerable portion of the girls with a later science & health profile are nevertheless very similar to those for the boys with a later science & technology profile. Given that the aim of the Dutch government is to stimulate greater STEM study choice, the question of whether the development of two science profiles was such a good idea can be raised. Pupils who opt for the lower degree of maths and science associated with the science & health profile depart from the main route to a later STEM course while this is largely unnecessary in terms of achievement. Although it is true that pupils who successfully complete the science & health profile are also admitted to most of the subsequent STEM courses, these pupils nevertheless have a lower starting level than pupils coming from a science & technology profile.

In previous research on the determinants of the choice of maths and science subjects (van Langen et al., 2004, forthcoming), an interaction effect was observed for the highest level VWO pupils. The interaction involved sex, parental level of education and ethnic origin. More specifically, minority girls with low educated parents chose more maths and science subjects than minority girls with high educated parents while the opposite held for the – much larger – group of native Dutch girls. In the present study of the choice of a science profile, however, no significant differences between the minority and native Dutch pupils were observed. Since the introduction of the study profiles, the highest level of secondary education has thus become more meritocratic with respect to ethnic background: The accessibility of maths and science education for native Dutch and minority pupils appears to be equal.

In the second phase of the analyses, just which factors – after pupil achievement, sex and parental level of education – still contribute to the degree of maths and science in the chosen study profile was examined. Twelve variables concerned with the individual pupil and his or her parents and two variables concerned with the school were found to stand out in the analyses. In the subsequent sex-specific analyses, yet another pupil variable was found to play a significant role as well. The 78% of the total amount of variance in the dependent variable explained by these variables is very high. But the question of whether these findings provide evidence for the meritocratic or reproductive character of Dutch secondary education (or at least the upper levels of Dutch secondary education) remains to be answered. Should the additional explanatory variables be interpreted in conjunction with pupil achievement (i.e., aptitude) or the sex and social background of the pupil? Unfortunately, this question cannot be answered unambiguously. If personal accomplishment or aptitude is understood in the widest sense of the word and such attitudinal characteristics as motivation and interest are also, thus, understood to be a part of pupil achievement or accomplishment, then a considerable portion of the variables found to exert a significant effect on the degree of maths and science in the chosen study profile can be construed as meritocratic. This certainly holds for the five variables from the category 'Pupil evaluations of subjects and teachers' which jointly account for the relatively largest part of the contribution made by the supplemental variables to the degree of maths and science in the chosen study profile. And along these lines, the report marks for chemistry, maths and physics, the desire to pursue a science/technical profession and learning style can be construed as operationalizations of motivation/effort, interest and innate dispositions, respectively. Whether such attitudinal variables should be treated as purely personal accomplishment and not – at least in part – as an outcome of socialization is very much the question.

Five variables from the category 'Advising and suitability of such according to third parties' – even after control for actual achievement – significantly influenced the choice of study profile and certainly do not belong to the category of personal accomplishment. It is striking that the recommendations of the parents, moreover, played a larger role than the recommendations of the school. Fifteen- and sixteen-year old children confronted with the choice of study profile are thus strongly influenced by their parents, and this finding is – by definition – not meritocratic.

Those school characteristics which influence the degree of maths and science in the chosen study profile can strengthen or neutralize the reproductive effects of social-demographic background characteristics. In our study, no school effects related to a particular social group or the gender of the pupils occurred. The finding that pupils choose a higher degree of maths and science on average when the school explicitly stimulates this nevertheless shows how schools can contribute to better utilization of the personal aptitudes and capacities of pupils.

Factors shown in previous research (van Langen at al., 2004, forthcoming) to influence the choice of maths and science subjects – after correction for pupil achievement and background characteristics – were: parental child-rearing style, degree of urbanization for the community in which the school is located and involvement of the grading committee in advising with respect to subject choice. In the present study, the contributions of these supplemental factors were no longer significant. This may be due to differences in the variable to be explained (i.e., number of maths and science subjects chosen in general versus degree of maths and science in the chosen study profile). Alternatively, the database for the present study was much more comprehensive at particularly the levels of the school and the pupil than before.

The contributions of all kinds of other school organization characteristics to the choice of a science profile were also studied quantitatively for the first in the Netherlands. This included analyses of the contributions of the following factors, among others: division of the choice of study profile into two phases with the choice of a general science or general society curriculum ('stream') made in the first phase and the choice of a specific profile only made later; combined teaching of chemistry and physics as a single subject in the years preceding the choice of study profile; and implementation of explicit measures and projects – for girls – in order to stimulate the selection of a science profile. However, none of these factors were found to significantly influence the extent to which pupils selected a science profile for secondary school study.

The Dutch government is striving to increase the number of individuals with a higher STEM education. On the basis of the present findings, it can be concluded that the meritocratic calibre of secondary education in the Netherlands – at least with respect to the selection of a science profile – leaves much to be desired. As a result of this situation, optimal use is currently not being made of the available maths and science talent – particularly for girls. And assuming that the attitudes of pupils – and their parents – are not purely related to aptitude, a change of attitudes within the present policy context still appears to be the obvious means to realize a greater choice of science profiles among both boys and girls.

Notes Chapter 4

1. The distinction between a partial versus complete subject curriculum was only introduced in 1998. The HAVO level does not have a partial chemistry curriculum; in both the science & health profile and science & technology profile, the entire chemistry curriculum is thus mandatory. In 2007, the partial subject curricula are going to be abolished due to an overfull and disjointed study programme.

2. At the HAVO level, 69% of the boys and 39% of the girls with a science & technology profile progress to a STEM course while 39% of the boys and 11% of the girls with a science & health profile do this. At the VWO level, 72% of the boys and 46% of the girls with a science & technology profile progress to a STEM course while 32% of the boys and 15% of the girls with a science & health profile do this.

3. The difference is that a strategic choice of elective subjects in the new situation can enhance one's admission possibilities. Pupils with an economics & society profile can improve their prospects considerably, for example, with inclusion of maths B as an elective subject.

4. All VOCL data collection occurred via the schools. Some of the schools terminated their participation completely, which meant that both the school and all the pupils from that school were no longer part of the cohort. Other schools participated to a more limited extent over time; they thus provided information on the annual position of the cohort pupils, for example, but no longer administered the tests and questionnaires. One can also speak of dropout at the level of the pupil due to change of school or repetition of a year. At the same time, new pupils entered the cohort after the first year. The latter have not, however, been included in our analyses due to a lack of important basic data.

5. Five pupils were further removed because they were the only pupils coming from a particular school, which must be avoided in multilevel analyses involving ordinal variables.

6. The measures were: primary school recommendation for level of secondary school (0.4 higher on a scale of 1-10); national achievement test scores from final year of primary school (2.3 points higher on a scale of 501-550) (see further in text); tests of Dutch language, maths and information-processing skills in the first year of secondary school (0.5, 0.7 and 0.7 points higher, respectively, on a scale of 1-20).

7. The differences were 0.15 for English and 0.12 for maths, both on a scale of 1-10.

8. Attention is thus not paid to which maths and science subjects were taken as an *elective* by the pupils in our sample (also see note 3). This information was not yet available at the time of the present analyses. The profile information nevertheless provides the most important information with regard to subject choice and particularly when it comes to the selection of maths and science subjects. The national examination results for the school year 2001/2002 show the percentage of HAVO pupils completing the final examinations for a science profile to only be a few percentage points lower than the percentage of HAVO pupils completing the final examinations for either the partial or complete chemistry, maths B and physics curricula (i.e., a difference of 4% at most). This means that beyond the pupils who have opted for a science profile, very few pupils freely choose maths and science subjects for study at the HAVO level of secondary education. The same holds for the girls in the highest levels of secondary education (i.e., VWO). Only for the boys in the highest levels of secondary education was the

difference larger with a maximum of 9.3%, which means that a considerable number of VWO boys who have opted for a society profile nevertheless select maths and science subjects as electives.

9. The rough association to the dependent variable was examined with the aid of one-way ANOVAs and chi-square tests; first univariate and then per level of education (i.e., HAVO, VWO) and for boys and girls separately. There was no reason to assume that the omitted variables would prove significant in interaction with other variables.

10. The evaluations of the subjects of Dutch language and maths – note that in the third year of secondary school, the distinction between maths A and B is not yet made – were elicited using a single item with four response categories ranging from 1 (= dislike) to 4 (=really like). The opinions regarding the teachers per subject were elicited using six items with four response categories, but the reliability analyses called for omission of two items. The final scales were found to have a reliability of α=.78 (Dutch language teachers) and α=.83 (maths teachers)
With regard to the importance of the different subjects to the pupils, the response possibilities ranged from 1 (= this subject is not important for me) to 4 (= this subject is very important for me). The reliability analyses produced a value of α=.51 for the three foreign languages and a value of α=.90 for the three maths and science subjects.
The responses to the propositions regarding the subjects – on the one hand – and the teachers – on the other hand – of French, physics and economics were elicited using 18 and 16 items, respectively, with three response categories ranging from 1 (= untrue) to 3 (= true). The results of a factor analysis produced four scales per subject with a reliability range of α=.71 to α=.95 and four scales per teacher with a reliability range of α=.61 to α=.91. The number of items per scale varied from three to six.

11. Dutch report marks range, in principle, from 1 to 10. The scales representing the third year report marks had a reliability of α=.69 for the three foreign languages and α=.89 for the three maths and science subjects.

12. The question regarding the four study profiles had the following response options· 1=profile is not recommended; 2=no recommendation or non-recommendation of profile; 3=profile is recommended; and 4=have no advice with respect to this profile. The responses were later recoded as follows: 1 = -1; 2, 4 = 0; and 3 = 1. The school recommendation with respect to each study profile was then calculated as the average of the teachers, study adviser and guidance counsellor with a maximum of two missing values allowed (i.e., not all of the schools involved all of these individuals in study choice advising). The reliability of the school advising scale was found to be above α=.97 for all four profiles. The recommendations of the parents with respect to the four study profiles involved the same response categories as the school recommendations.
For the judgements of the suitability of the complete – and not, thus, the partial – physics, economics and French subjects, the response categories were: 1=unsuitable; 2= not unsuitable, not suitable; 3=suitable; and 4=I do not know. The subject suitability responses were later recoded as follows; 1 = -1; 2 = 0; 3 = 1; and 4 = missing. Subject suitability according to the school was calculated as the average suitability according to the teachers, study adviser and guidance counsellor with a maximum of two missing values allowed. The reliability of the school suitability scale was found to be above α=.96 for all three subjects. The subject suitability judgements of the parents involved the same response categories as the school judgements.

13 The responses to the question regarding the motivation for the expected profile choice varied from 'I'm most interested in that' and 'because I'm good at those subjects' (both intrinsic) to 'I need it for further education' (extrinsic) The level of educational aspiration for both the pupils and parents could vary in value from 2 (=vocational education) to 7 (=university) The response category 1 (=I do not know) was later treated as a missing value The question regarding career characteristics involved 25 items with four response categories ranging from 1 (=does not apply) to 4 (=applies very well), which were exactly the same as reported by Kuyper, van der Werf & Lubbers (1999) but in our database produced somewhat different factor results One item (i e , 'lots of involvement with children') had to be omitted due to high loadings on multiple factors The reliability of the resulting six scales ranged from α= 59 to α= 72, the number of items per scale varied from three to five The question addressing the interest of the pupil in a variety of educational/training disciplines involved 19 items with four response categories ranging from 1 (=I do not find interesting) to 3 (=I find interesting) Response category 4 (=I do not know) was treated as a missing value The reliability of the five interest scales ranged from α= 56 to α= 80, the number of items per scale varied from two to four

14 The question regarding study behaviour involved 18 items derived from Pintrich and de Groot (1990) and Roosendaal and Vermunt (1992) The response categories varied from 1 (= (almost) never) to 5 (= (almost) always) The items formed three scales with five to seven items each The 'integrative' strategy involves such items as 'when I prepare for examinations, I try to combine the information from the lessons with what is in the book ' An item belonging to the 'concrete' strategy is 'as I review the material, I repeat certain words to myself in order to remember them better ' And an example of the 'extra work' strategy is 'I also aim at objectives which are not handled as part of the subject matter ' For information on the reliability of the scales, the reader is referred to Kuyper et al (2003)

15 The variable 'guidance counsellor' indicates whether this person 1) has direct contact with pupils, 2) steers teachers and study advisers from the background or 3) a combination of the above The variable 'involvement guidance counsellor' indicates the extent to which the guidance counsellor is involved in seven school activities associated with profile choice advising The dichotomous variable 'recommended profile' indicates the steering nature of the advice which the pupils receive, some schools specifically recommend a *single* profile while other schools do not The variable 'teacher' indicates the involvement of the individual subject teachers in the provision of guidance with regard to the choice of study profile and can vary from 'only indirect via report marks' and 'teachers provide advice with regard to their own subject' to 'teachers (also) provide advice with regard to the profile ' The variable 'interest characteristics' indicates whether the school considers achievement and marks more important, less important or equally important as personal interest in the determination of profile choice The variable 'importance of follow-up' indicates the extent to which the school (in the eyes of the respondent) considers steering towards the choice of study profile with the most follow-up education possibilities to be important along a scale of 1 to 5 Four other connected dummy variables involved mutually exclusive characterizations of the school policy with respect to the choice of study profile 'school stimulation 1' or the school stimulates pupils as much as possible to select a science profile, 'school stimulation 2' or the school strives towards an even distribution of the pupils across the four profiles, 'school stimulation 3' or pupils may only choose a science profile when it is clear that they can handle this, and 'school stimulation 4' or the school tries to steer pupils as little as possible in the direction of a particular study profile The variable 'projects' indicates schools which organize joint projects with the maths and science teachers as part of their teaching The variable 'best teacher' indicates schools which intentionally place their best maths and science teachers in those classes where the choice of

study profiles and subjects occurs. Finally, the variable 'nask3' (i.e., *natuurkunde* plus *scheikunde*) indicates whether the subjects of physics and chemistry are taught together as a single subject in the third year of the upper levels of secondary education (i.e., HAVO, VWO).

16. In order to compare the effects to each other, not only the continuous but also the dichotomous variables are transformed into z scores. While transformation of the latter is generally not recommended due to poor interpretability (see, among others, Snijders & Bosker, 1999), we judged it to be legitimate in light of the objectives of the present research.

17. On the maths test, the boys with a science & technology profile had an average score of 77.4 with a SD of 13.4; the grils with a science & health profile had an average score of 73.7 with a SD of 13.3. The average report mark for chemistry, maths and physics in the third year of secondary school for the boys was 7.5 with a SD of 0.8; for the girls, 7.2 with a SD of 0.8. All of this means that 94% of the girls with a science & health profile had a maths score which was never any less than two standard deviations below the average maths score for the boys with a science & technology profile and that the maths and science report mark for 93% of the girls was never any less than two standard deviations below the average report mark for the boys. On the basis of the hypothesis that no differences exist between the groups, the percentage should be 97.5%.

18. With the ordering of the variables in Table 4.2 according to the size of their effect, we do not mean to suggest that the relevant regression coefficients all differ significantly from each other. This presumably does not hold in every case.

19. The older percentages were calculated on the basis of 5086 pupils from the VOCL'93 cohort which constituted the research sample for the previous study by van Langen et al. (2004, 2005).

5 Cross-national differences in participating in tertiary science, technology, engineering and mathematics education*

5.1 Abstract

In many western countries attention is currently being given to the participation of students in tertiary Science, Technology, Engineering and Mathematics (STEM) education This is a result of internationally competing economic ambitions, coupled with acute shortages on the STEM labour market, a declining interest among students for STEM education and a long-lasting underrepresentation of women However, despite similarities concerning policy attitudes and identified problems, western countries differ considerably from each other concerning the percentages of students that choose STEM education and the proportion of female students included here Based on an in-depth study in Sweden, the United Kingdom, the United States and the Netherlands, this chapter investigates the reasons for these cross-national differences At the heart of the explanations lie the accessibility of the STEM pipeline, the level of broad-based interdisciplinary studies as opposed to compartmentalisation and early specialisation, labour market characteristics, social traditions and government policies

5.2 Introduction

Much research has been carried out in recent decades into students (not) choosing mathematics and science subjects in upper secondary school and Science, Technology, Engineering and Mathematics (STEM) degree courses in higher education A considerable part of this research was sex-related Even though the number of girls and women participating in the highest levels of education has become comparable to or even higher than the participation of boys and men in most western countries for several years now, within this, sex-related choice differences still occur After controlling for capacities and achievements, female students still choose maths and science subjects in secondary school and STEM courses in higher education far less frequently than male students Over the years much information

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has been collected on the characteristics at student, family and school level that contribute to explaining these sex-specific, choice differences (van Langen et al., forthcoming).

In recent times the research focus has shifted from the sex-specific nature of STEM choice to explaining the underutilization of potential STEM talent of both men and women. This was triggered by the decrease in most western countries in the supply of highly educated STEM personnel, thereby creating a seriously threatened shortage of such workers on the job market (Cervantes, 1999; CAWMSET, 2000; Roberts, 2002; Jordan & Yeomans, 2003; ROA, 2003;). The subject is even more relevant within Europe since the European Council announced the ambition in Lisbon in 2000 that over the next ten years the European Union should become the most dynamic and competitive knowledge economy in the world. This ambition has been worked out in the form of several benchmarks, including the aim of increasing the number of STEM graduates (European Commission, 2002, 2003a) and reducing the imbalance between men and women within this sector.
Even though a shortage of highly educated STEM personnel has been identified in most western countries and sex stereotypical education choices are an international phenomenon, it is unclear to what extent countries can actually be compared on this point and what could be the possible explanations for any cross-national differences. This chapter reports on an international comparative, in-depth study in which these questions were further examined. So this time explanations were not at individual, background and school level but within the context of societal and system factors that influence the choice of STEM courses.

Analyses tapping into underused STEM potential have been carried out, among others, at two crucial choice moments in school careers: the choosing of a STEM course in tertiary education (ISCED [International Standard Classification of Education] level 5A or higher (OECD, 1999)) and prior to that, the choosing of maths and science subjects in the higher types of upper secondary education (ISCED level 3A, preparing directly for 5A). The latter level is usually a vital factor for gaining direct entry to the former level. At both choice moments 'spillage' from the so-called STEM-pipeline (or 'pathway') can occur if students, although academically qualified, choose other subjects or courses. The prevention of this could help remove or reduce the identified shortages on the job market.

This study focuses on these two moments of choice but because of the gender-related nature of subject and course choices, attention is given to both the choices of students in general and to those of female students in particular. The following research question formed the basis of our study: how can differences in percentages between countries regarding general and sex-specific choice of STEM courses in higher education be explained, and to what extent does the choice of maths and science subjects in upper secondary education play a role?

In the present study, the STEM courses were defined as: physics and chemistry, manufacturing and processing, architecture and building, engineering and engineering trades, computer sciences, mathematics and statistics. Maths and science subjects in upper secondary education were defined as mathematics, physics and chemistry since they are the major qualifying subjects for STEM courses[1].

In the following sections we first review an inventory of choice percentages in a number of countries. For reasons of feasibility, accessibility and relevance it was decided to limit this to the then 15 EU member states, (i.e., before April 2004), plus the United States (US), providing there were data available. The inventory is followed by the set-up, theoretical framework and results of an in-depth study carried out in four countries: Sweden, the United Kingdom (UK), the US and the Netherlands.

5.3 STEM choices in higher education

In various European Commission reports, including one in 2004, we encountered overviews of percentages of students enrolled for STEM courses compared to the higher education student population as a whole. However, these figures do not distinguish between individual STEM subjects, sex of students or specific tertiary education level (ISCED-level 5A or 5B) and obviously the US is missing from these European statistics. An alternative was offered by the OECD (2003), which collected statistics for a large number of countries on the proportion of graduates per course studied in relation to the whole. Even though theoretically there can be considerable differences between the percentage of choosers and graduates for each course, because of differences in student drop-out, this is a good measure of course uptake. Table 5.1 presents the figures concerning the percentage of graduates in 2001 in the four STEM related fields of study as distinguished by the OECD (2003). Unfortunately, Greece, Ireland, Portugal and Luxembourg are missing from the OECD's figures.

We point out that the percentages in Table 5.1 relate to relative graduation rates, i.e. graduates in STEM courses over other courses at the same education level. Thus the fact that the proportion of the population that participates in education at this level is not comparable between countries was disregarded.

Table 5.1 – Proportion of graduates in tertiary education ISCED level 5A in STEM fields of study in 2001. Source: OECD (2003)*

	Engineering, manufacturing &construction	Physical sciences	Mathematics & statistics	Computing	Total
Austria	18.7	2.8	0.7	2.2	24.4
Belgium	12.5	2.4	0.8	2.0	17.7
Denmark	9.0	2.8	0.5	0.8	13.1
Finland	20.8	2.2	0.9	2.5	26.4
France	11.2	5.8	2.9	2.6	22.5
Germany	18.4	5.2	1.7	3.1	28.4
Italy	15.9	1.6	2.1	0.8	20.4
Netherlands	10.5	2.3	0.2	1.6	14.6
Spain	14.2	3.2	1.3	3.4	22.1
Sweden	21.5	2.5	0.6	3.5	28.1
UK	10.5	5.2	1.4	5.0	22.1
US	6.4	1.5	0.9	3.2	12.0

* Including advanced research programmes

Table 5.1 reveals considerable differences among the countries. From all the higher education graduates at ISCED level 5A or higher in 2001, less than 15% in Denmark, the Netherlands and the US had graduated in a STEM field of study compared to more than 28% in Sweden and Germany.

Table 5.2 shows the percentage of female graduates for these subjects for each country in 2001. This information is obtained on request from the OECD. In the last column the average of the previous columns is given, thus ignoring the fact that the absolute number of graduates in the fields of study is not equal.

Table 5 2 – Percentage of tertiary ISCED level 5A qualifications awarded to females in STEM fields of study in 2001 Source OECD, upon request*

	Engineering, manufacturing & construction	Physical sciences	Mathematics & statistics	Computing	Mean
Austria	17 3	27 3	40 8	11 0	24 1
Belgium	20 4	35 1	45 5	16 3	29 3
Denmark	22 5	35 4	45 0	19 2	30 5
Finland	19 4	45 4	39 1	33 9	34 5
France	23 8	37 5	43 3	19 2	30 9
Germany	20 5	28 0	44 1	12 1	26 2
Italy	27 6	42 3	62 5	27 1	39 9
Netherlands	12 4	25 7	26 9	14 0	19 8
Spain	28 5	51 1	55 1	23 4	39 5
Sweden	27 8	43 0	35 9	40 1	36 7
UK	19 3	39 8	40 4	24 8	31 1
US	21 4	38 2	45 3	29 2	33 5

* Including advanced research programmes

The underrepresentation of female graduates in the STEM fields of study is generally higher in engineering, manufacturing and construction, as well as in computing, than in physical sciences or mathematics and statistics The cross-national differences for all columns are considerable Noteworthy are the high percentages of Spanish and Italian female graduates in mathematics and statistics and for Spain also in physical sciences, thereby giving these countries the highest mean in the final column

5.4 Maths and science choices in upper secondary education

Originally we also intended to make an inventory of maths and science subject choices in upper secondary education (ISCED level 3A) in the EU countries and the US and to compare the choice percentages However, this turned out to be not really feasible By means of searches on the internet and approaching national statistical agencies and education departments, data were collected on the choice of maths and science subjects for most EU countries and the US For a few countries this was unsuccessful either because there was not a national register or because of a lack of response A greater stumbling block, however, was that the gathered data could in no way be compared owing to the huge differences in upper secondary education systems between nations In the first place this applies to the degree of streaming in secondary schools, i e the homogeneous grouping of pupils based on ability Where this is not done – as in the US – no specific ISCED level 3A can be distinguished from 3B or 3C The differences also relate to the number of subjects that pupils have to choose (in the UK, for instance, a maximum of four academic subjects, in the Netherlands around eight), the possibility of complete freedom of choice versus compulsory subjects or combinations of subjects and programmes, and a choice between taking maths and science at one level or several different levels Moreover, sometimes the figures relate to the number of choosers, sometimes to the number of successful passes, and countries differ on whether they discount students in part-time and adult education Eventually, we decided not to present the collected data here Only the maths and science subject choices of the four countries studied in-depth are taken as much as possible into account and presented in Appendix D They also provide a good illustration of the problems identified when making cross-national comparisons at this educational level

5.5 Design of in-depth study

The research question was answered by carrying out an in-depth study in Sweden, the UK[2], the US and the Netherlands Between October 2002 and December 2003 interviews were held with five or six experts from each country, either working in education research or education policy or in organizations expressly attempting to promote the participation – of girls and women – in maths and science subjects, STEM courses and/or STEM professions The respondents were chosen because their jobs gave them a good overview of the national situation in the research field concerned Interviews were carried out on the basis of a topics list, which is further explained in the next section Following this, all the recorded interviews were transcribed and supplemented with additional information from research reports and other documentation

The four countries were selected mainly because of inventoried data on choice percentages in higher education, which are again summarized in Table 5 3 Other reasons included the accessibility of written documentation on the countries Obviously the Netherlands was involved in the study because of the origins of the researchers The differences between the four countries regarding general and sex-specific STEM course choice percentages, expressed as rankings in Table 5 3, were the variables to be explained in the in-depth study

Table 5 3 – Overview of the differences among the four countries studied regarding the general and sex-specific choice of STEM courses in tertiary education (derived from Table 5 1 and 5 2)

	General	Rank	Sex-specific	Rank
Netherlands	14 6	3	19 8	4
Sweden	28 1	1	36 7	1
UK	22 1	2	31 1	3
US	12 0	4	33 5	2

5.6 Theoretical framework of the in-depth study

In 1999 Dekkers presented an interdisciplinary model of mutually related variables to explain education choices The model is based on the assumption that mutually influencing factors at family, student, school and class level determine the final outcome and that this combination of factors, in its turn, is influenced by the social context of a country In recent decades much international research has been done into student, family, school and class variables that influence subject and study choice (for an overview see van Langen et al , forthcoming) However in the present in-depth study the social context level was central since to find explanations for choice differences between countries it is logical these should be sought within this context (Bradley & Charles, 2004) In the literature we find four categories of social context characteristics that can influence subject and course choice in general, or maths and science subjects/STEM course choices in particular

Firstly, there are education system characteristics Brown (2001) argued that by expanding the number of A-level subjects that must be chosen, UK sex differences in subject and possibly also occupational choice would decrease Bradley (2000), Charles and Bradley (2002) and Bradley and Charles (2004) found an association between greater sex segregation across fields of study and (a) education systems that maximize individual freedom of choice by eliminating mandatory requirements, (b) differentiated, vocationally-oriented secondary systems as opposed to comprehensive secondary systems, and (c) diversified tertiary systems

Secondly, characteristics of the job market and economy play a role Based on rational choice theory, Bradley (2000) as well as van der Werfhorst et al , (2003) explained sex and social background differences in study choice by differences in the way male and female students and different social classes prioritize the benefits and drawbacks of various professions (e g , economic and social rewards) Kalmijn and van der Lippe (1997) and Turner and Bowen (1999) came to similar conclusions In general when choosing an area of study, male students react far more strongly to economic developments than female students and job prospects are a more important choice motive for STEM students than for other students (van den Broek & Voeten, 2002) Hanson et al (1996) found a negative association between economic development and female participation in science Baker and Jones (1993) established a link between women participating in the job market and the percentage of women in industrial professions, on the one hand, and girls' access to maths curricula, on the other

A third category relates to social views and traditions Roger and Duffield (2000) contended that in Scotland, the stereotypical image of STEM areas of study – boring, masculine and remote from everyday life – is an important factor for the general lack of interest Hanson et al (1996) and Hanson et al (1999) argued that the ideological climate in Finland as well as in former East Germany, where gender equity is (or was) a priority, largely accounts for the high numbers of women in higher STEM professions Bradley and Charles (2004), however, stated that 'cultural (attitudinal) gender egalitarianism' (p 259) has a stronger effect on overall female participation in higher education than on female representation in historically male fields of study

The final category we distinguish is government policy, even though this partly overlaps with the three other categories The government determines many of the aforementioned elements of education systems and the labour market through educational and labour legislation Moreover, government campaigns are often aimed at influencing social attitudes (Dekkers, 1996) Charles (2003) established that government removal of formal legal barriers (creating structural, as opposed to cultural, gender egalitarianism – Bradley & Charles, 2004) is not sufficient, but is the first step on the way to creating equal participation by both sexes in all education sectors and on the job market (see also Wilson & Dekkers, 1998) Government influence is expressly present in the funding of education reforms and experiments to promote interest in STEM subjects (Jordan & Yeomans, 2003)

5.7 Results

The aforementioned social context characteristics formed the basis for the interviews carried out in the in-depth study The questioning centred on what aspects of these characteristics influence, or have influenced, male and female students in Sweden, the UK, the US, or the Netherlands in choosing maths and science subjects or STEM courses In a separate publication (van Langen & Dekkers, 2005a) we elaborately discuss these explanations for each country, preceded by a brief outline of the situation in a particular nation In the next sections, our findings are summarized to give a general overview and provide an answer to the formulated research question

The aim of the in-depth study was to find explanations for the general and sex-specific differences in the percentages of students choosing STEM courses among the four countries, and to look at how far choosing maths and science subjects at secondary school level played a role. During the interviews, we noted that a number of explanations for the specific national subject and course choices were mentioned by the respondents or in documents in all four countries. While it is impossible to investigate precisely whether the countries differ in the extent to which these factors play a role, it does mean for the moment that these factors are the same for all four countries and thus they offer no clear-cut explanation for cross-national differences in the choice of STEM courses. What remains are systematic context characteristics in which the four countries do differ and which could explain cross-national choice differences in general, and those of female students in particular. In the next sections, both the similarities and differences between the four countries are described in more detail.

5.7.1 Similarities in relevant context characteristics

Despite the presented cross-national choice differences in STEM courses, in all four countries studied the choice of maths and science subjects at secondary school level and STEM degree courses at higher education level is currently a problematic issue owing to a general declining interest, an underrepresentation of girls and women, acute shortfalls on the labour market and high economic ambitions. Thus in every country attempts have been made to analyse the lack of interest for these subjects. This has led to partially similar findings, which are arranged below according to the aforementioned categories of social context characteristics.

Education system: quality of STEM education and shortage of teachers

The quality of secondary and tertiary (possibly also primary) STEM education is mentioned in all countries as an important negative factor that does not contribute to young people's interest in STEM courses and professions. This education is generally seen as inaccessible, not relating to young people's everyday world and not paying enough attention to the relevance for society and the future. In secondary education subjects are insufficiently linked and teaching methods are mainly traditional: conservative teaching methods, a competitive atmosphere, and few active work forms and hands-on experiences for students (Grevholm, 1996). STEM courses in higher education are reported as too theoretical, insufficiently professionally oriented and not connected with secondary STEM education (Felsö et al., 2000). Part of the instruction is given in large-scale formal lectures, by lecturers who are often more focused on research than teaching.

All sources consulted point out that the objections concerning the quality of maths and science education and STEM courses play a greater role among girls than boys owing to the former's greater need for a sense of social usefulness, and practical orientated and cooperative education (Fennema, 1996)

A secondary problem is the shortage of maths and science teachers in secondary education (e g , Roberts, 2002, ROA, 2003), which has led to these subjects sometimes being taught by teachers who are not sufficiently qualified It is a vicious circle due to a lack of interest fewer students apply to train as maths and science teachers, so that standards in maths and science education drop and the interest from students for these subjects declines further

Job market demanding STEM jobs without sufficient rewards and opportunities

A negative influence mentioned in all countries is that jobs in the STEM sector are known to be demanding and inflexible (Schiebinger, 1999), while the rewards are no greater than for other jobs with respect to salary, career prospects or working conditions (Roberts, 2002) According to recent analyses by both the Dutch and the British government, inflexible working conditions are one of the major reasons for the fact that only a minority of professional workers with a STEM educational background are actually employed in a STEM profession Other causes are the perceived lack of career perspectives and opportunities, as well as the fact that these graduates are much in demand in other sectors such as finance and banking (DTI, 2002, Kabinetsnota, 2003)
Moreover, most jobs in the STEM sector are full-time and it is certainly more difficult in this sector to work part-time or take a few years out The respondents pointed out that therefore, it is only women intent on making a career for themselves who choose this sector Besides, girls have few role models or mentors in the STEM sector because of existing sex segregation on the labour market (Greenfield et al , 2002)

Social views and traditions STEM is stereotyped as difficult, inaccessible and for males

The STEM sector, as perceived in the media, is given a strongly stereotypical image as being too difficult, unappealing and unglamorous (Hop et al , 1999, European Commission, 2001) Scientists and technologists are predominantly painted as male, eccentric 'geeks' and 'nerds' For this reason many young people in the four countries studied who have the potential to follow a higher STEM course reject this, just as was established in Scotland (Roger & Duffield, 2000) From a study by the Commission on the Advancement of Women and Minorities in Science, Engineering and Technology Development (CAWMSET) (2000), it emerged that Americans are interested in science and technology but find it difficult and inaccessible An exception until recently was computer science Under the influence of the IT hype, in the 1990s it was considered 'hip' and students, especially male ones, were attracted by the money to be made

Many maths and science teachers and STEM lecturers confirm this stereotypical image by giving the impression that their area of study is a tough course in which only the best can succeed (Seymour & Hewitt, 1997) Moreover, in the three European countries studied most STEM courses in higher education are longer than other ones While this is not necessarily the case in the US, a Bachelor's degree in a STEM major, unlike other many other subjects, offers little prospect on the US job market so most STEM students go on to the post-graduate programmes

It is also thought that school counsellors and career advisers perhaps give sexist and other stereotypical advice In 2002 a government-sponsored report was published in the UK (Greenfield et al , 2002) which stated that young girls, who already lack appealing role models in their immediate environment working in the STEM sector, are insufficiently informed about STEM courses and careers Also, girls could be under pressure from their peers to choose traditional female subjects

Government policy – and other initiatives to enhance STEM participation

Not only were the aforementioned explanations commonly advanced in the countries studied, but there are also similarities in the initiatives adopted in recent years to turn the problem around and to promote the interest for STEM education and jobs The most important initiators are governments and government-funded institutes for primary, secondary and higher education But there are also numerous, sometimes international, socially oriented bodies active, including associations of (female) STEM teachers and other professional STEM groups And sometimes the STEM industry itself initiates new plans, partly prompted by its inability to recruit personnel

Repeatedly found initiatives in STEM education include curricula reforms (e g , inquiry-based education), revising textbooks and student information, inviting STEM companies into schools or universities and vice versa, the setting up of educational centres, in-service training for teachers, developing new multi-disciplinary degree courses and setting up mentor and tutor systems and networks (Kerstens, 2004) Some of these initiatives explicitly focus on non-traditional groups such as women and minorities (Wistedt, 1998)
Recurring out-of-school activities include the developing of popular science television programmes, magazines and instructive science and technical centres and organizing summer camps and competitions On the labour market, larger

companies like IBM are experimenting with flexible working conditions and family-friendly personnel policies

Depending on the extent, length of time and actual effect of such initiatives, these could go some way in explaining the cross-national differences in STEM choices However, this is hard to determine since these are non-structural or recent initiatives, which have often not yet been systematically assessed, so for the moment it is unclear to what extent the countries differ in this respect

5.7.2 Explanations for cross-national differences in the general choice of STEM courses

From the results of the in-depth study, we conclude that systematic differences between the four countries could explain how the general cross-national STEM choice differences relate to the number of 'entry' points in different segments of the STEM educational pipeline, the costs of studying in relation to the drop-out risk, and the level of broad-based interdisciplinary studies as opposed to compartmentalization and early specialization These aspects, all relating to characteristics of the education system, are briefly described below for each country

Entries into the STEM pipeline

The ideal way to prepare for a STEM course in Swedish tertiary education is to complete the natural science programme in upper secondary education (Skolverket, 2000, see also Appendix D) However, for those who never followed this programme, there are good opportunities to get back on the STEM track again at a later age and much use is made of this Two government-funded options are available The first relates to adult education given by upper secondary schools in which students can still prepare for a university STEM education The second option is an extra preparatory year, which various universities and polytechnics have introduced During this basic year potential STEM students can plug relevant academic gaps, after which they are guaranteed a place on their chosen STEM course This preparatory year is an example of the kind of set-up the Swedish government expects of universities Instead of selection based on previous academic achievement, these institutes should be able to fill any missing achievement gaps The admission criteria are made lower where necessary and there are no restrictions on the number of places available It is mainly female students and students from lower social groups who make much use of this second-chance education

In the remaining three countries, students who want to study STEM subjects in higher education but have made the wrong choices in upper secondary education

find it more difficult to recover lost ground In theory they can catch up via summer courses or adult courses, but mainly at their own expense so only a few students take this path (e g , Maple & Stage, 1991)
An additional accessibility issue in the US is that the quality of the decentralized education system varies immensely As a result, not all high schools offer so-called AP (Advanced Placement) courses of a higher, more academic level (NCES, 2002) Nevertheless, American universities draw up their admissions criteria based on these courses (Hanson et al , 1996)

Study costs in view of drop-out risk

In all the countries studied the STEM courses in higher education on average take more time than others In this respect, no cross-national differences are found But the extended course can be more of a problem, especially for the socially disadvantaged, in countries where studying is expensive (Felso et al , 2000) and the drop-out risk is high
The general drop-out rate in higher education is highest in Sweden (survival rate in 2000 was only 48% for all tertiary-type A programmes, OECD, 2003) but on the other hand the provisions for student support are quite favourable The Swedish government's attitude is that those who need help in financing a course of study will receive it (RAND Europe, 2003) Student financing for higher education comprises a flexible combination of grant and loan, means-tested and dependent on qualifications obtained No tuition fee is charged

The drop-out rates in the US and in the Netherlands are fairly similar (survival rates in 2000 were 66 and 69% respectively for all tertiary-type A programmes, OECD, 2003), but tertiary education in the US is extremely expensive Tuition fees vary greatly, but in public institutions they were on average US$3356 in 1999 (Kaiser et al , 2001) Grants are awarded on a limited scale only, loans are available but many people do not dare to take these on In the Netherlands, students in higher education receive a conditional interest loan which, depending on course results, can be converted into a gift (RAND Europe, 2003) In 2001 a tuition fee of around € 1300 was charged (Kaiser et al , 2001)

In recent years there have been drastic cuts in student financing in the UK so that students now accumulate more debts than previously (CST, 2002) The tuition rate was £1075 in 2001 (Kaiser et al , 2001) On the other hand, higher education in the UK is well known for its higher amount of one-to-one contact between students and teachers than in other education systems and space for personal counselling and advice Thus drop-out rates, including those for STEM students, are small (survival rate in 2000 was 83% for all tertiary-type A programmes, OECD, 2003)

Broad-based interdisciplinary studies versus compartmentalization and early specialization

Typical of higher STEM education in the Netherlands is the strict compartmentalization of courses and the early degree of specialization required, which is not attractive for many prospective STEM students In recent years there has been a concerted effort to find solutions for these problems in the form of broader, interdisciplinary studies, new graduation options and so on At certain institutes the effects of this are visible and there appears to be a turnaround in the decline in student numbers (Kerstens, 2004) Nationwide, however, the problems have still not been resolved

In the remaining three countries this problem exists to a far lesser extent In Sweden, only half of the undergraduate programme in higher education must be devoted to the main area of study (Hogskolverket, 2000) while the other half can be chosen from any number of courses In the UK, some of the undergraduate courses in higher education specialize straight away, while others are initially broad-based and specialize later The first two years of US tertiary education are broad-based and the choice of a major is made only in the third year (Bowman, 2004) As an exception, the engineering programmes already start in the first year of tertiary education (NSB, 2000) The figures in Table 5 1 show that participation in this STEM field of study is lower for the US than for other countries

5.7.3 Explanations for cross-national differences in the female choice of STEM courses

Table 5 4 presents figures on female participation in the labour market and employment patterns for families with young children, public expenditure for childcare and parental and maternity leave legislation for all of the countries studied From the results of the in-depth study, we conclude that systematic differences in these characteristics of the job market, social traditions and government policy offer an explanation for the cross-national differences in STEM participation by female students The fact that these are important factors was also established by the European Commission (2003b), which in a supplementary dossier goes into the issue of female underrepresentation in science and technology in Europe Again, we illustrate this below by describing each aspect in short

Table 5.4 – Figures for the job market, employment, childcare and leave provision in the four countries studied. Sources: Jaumotte, 2003; UNDP, 2004

	Netherl	Sweden	UK	US
Female economic activity rate* in 2002	45.8	62.7	53.2	59.3
Female employment in industry (as % of female labour force) 1995–2000	9	11	11	12
Employment patterns couple families with child under 6 in 1998				
Man full-time, woman full-time	4.8	51.1	24.9	x
Man full-time, woman part-time	54.8	13.3	31.9	x
Man full-time, woman unemployed	33.7	24.9	32.8	x
Other	6.7	10.7	10.4	x
Public expenditure childcare				
Purchasing Power Parities (PPP) – US$ per child in 1995	2025	5530	1850	1803
% Gross Domestic Product (GDP) in 1999	0.6	1.9	0.5	0.5
Maternity, parental & childcare leave in 1999				
Maximum number of weeks	29	85	31	12
Paid	16	40	8	0

* The proportion of the female population aged 15 and above that supply, or is available to supply, labour for the production of goods and services

Female participation in the labour market and provisions for child care and parental leave

Most jobs in the STEM sector are still full-time and, moreover, are known to be demanding and inflexible (Schiebinger, 1999). According to sources consulted, this is a common reason for the low numbers of female STEM students in all four countries studied. The extent to which this is a problem, however, depends on the full-time participation of women in the labour market, possibly coupled with the availability of (affordable) child care and parental leave (Baker & Jones, 1993). Table 5.4 reveals considerable differences among the countries in these aspects.

Sweden has outstanding social provisions. Childcare is available and affordable and there are good arrangements for parental and maternity leave – by and large salaries continue to be paid. Partly as a result of this, Swedish women participate in the labour market to a relatively high degree (51%), although in view of the staggering income tax this is also due to economic necessity (Gunnarsson et al., 1999).

Maternity and parental leave provisions in the UK are quite limited Childcare is not widely available and is expensive according to the Greenfield report (2002) the UK scored the lowest in Europe on this point Partly as a result of this, only 25% of women with young children in the UK are working full-time

Unfortunately figures are missing for the employment pattern of American couples with young children According to the respondents, however, the full-time participation in the American labour market by dual earners is high due to economic need or, as others suggest, the sky-high standard of living Table 5 4 also shows that legislation for parental and maternity leave in the US is very limited Childcare is available but this is hardly funded

Legislation and allowances for maternity and parental leave in the Netherlands is slightly more favourable than in the UK, more restricted than in Sweden and more generous than in America Compared to the other countries, however, women's participation in the labour market is low, even though the percentage has increased sharply in recent years Dutch women are European front-runners when it comes to part-time jobs Recent research (Kuyper et al , 1999) shows that 15-year-old Dutch girls still expect to work part-time later while their partner has a full-time job A 1994 study (Jaumotte, 2003) showed that 45% of Dutch people agreed with the statement that a pre-school child is likely to suffer if his or her mother works The finding gives a good idea of the prevailing social views on working mothers This typically Dutch phenomenon probably goes a long way to explaining the lack of interest from prospective female students for STEM courses Moreover, the figures in Table 5 4 show the sex segregation and thus the lack of female role models in the industry sector in the Netherlands is even greater than in the other three countries

Government policy and social traditions with regard to gender equity

A final explanation for the cross-national differences in female participation in STEM courses relates to the extent to which government policy and social traditions include, and have included in the past, gender equity (Hanson et al , 1996, 1999, Charles, 2003, Bradley & Charles, 2004) Again, considerable differences are established between the four countries

A typical common feature of Swedish society is that gender equity has been around for a long time now In general the Swedish government has actively promoted equal chances and equal treatment for men and women for decades, which is evident by the position of women in society and on the job market

In the US too, the fight against educational inequality based on sex (as well as ethnicity) has been one of the federal government's major policy aims for some time and is coupled with a powerful women's movement (Hanson et al., 1999). In 1981 a law was introduced based on equal opportunities for women and minorities in science and technology. The development of this policy was always linked to gathering statistics, broken down according to sex and ethnic background, and the publishing of research findings (NSF, 1982, 2000). Some sources believe that this too has contributed to a great awareness among counsellors, parents and teachers to keep open the options of all students as much and for as long as possible.

In many ways the position of women in British society is not equal to that of men, although in the past few years this subject has been fairly high on the political and social agenda. The government's concern regarding the threatened shortfall in the STEM sector is apparent from several reports and white papers on the subject (e.g., Greenfield et al., 2002; Roberts, 2002; DTI, 2003). For about 10 years now attention has focused on the underrepresentation of women in this sector. In 1994 the Promoting SET (Science, Engineering and Technology) for Women Unit was set up within the Department of Trade and Industry (DTI).

In the Netherlands there is little awareness that subject and course choices are much more sex-specific than in most other western countries and that this leads to lower opportunities for women in the labour market. Specific initiatives to promote more female participation in STEM education are thus often dismissed out of hand or not taken seriously. Only a few months ago, the Dutch minister of social affairs claimed that women's emancipation in the Netherlands had been accomplished. According to some respondents, this 'myth of achieved women's emancipation' can be clearly seen in Dutch government policy, for instance by the fact that figures on participation in various courses and job sectors are not always broken down according to sex. In contrast, since 1984 the Dutch government has set up various national campaigns to promote women's participation in STEM education. In general, however, these had little or no effect on the inflow (Dekkers, 1996).

5.7.4 The role of maths and science subject choice in secondary education

An express part of the research question concerned the role maths and science subject choices at secondary school level play in explaining general and sex-specific differences in the taking up of STEM courses in higher education. We established that this choice in the UK, the Netherlands and the US is practically a condition sine qua non for the later STEM course choices. In Sweden there are more opportunities to enter the STEM pipeline at a later point in secondary school, although here too the ideal route to a STEM degree course is via the natural science programme at upper secondary level. In view of this prerequisite link, it is relevant to look not only at the influence of social context characteristics on choosing STEM courses, but also at maths and science choices made earlier on in the school career. Attention given to this in the in-depth study resulted in several stimulating and impeding factors for each country. However, since the extent of choice for maths and science subjects in the four countries is difficult to compare due to structural differences in the education systems (see also Appendix D), we were unable to establish precisely how far these explanations are responsible for cross-national differences in maths and science choices. What we can examine is whether these differences between secondary education systems in themselves explain differences in the choosing of STEM degree courses in the four countries. The four education systems vary on at least three points:

1. Broadness of the curricula. In Sweden and the Netherlands pupils are taught a broad range of subjects until the end of secondary school, while UK pupils specialize in three or four subjects in their A-level years and US pupils can belong to either of these groups due to the great degree of individual differentiation;
2. Extent of differentiation. Upper secondary education is comprehensive in the US (with individual streaming via differences in course taking), while formal streaming exists in the other countries but starts at different ages: in Sweden and the UK differentiation is delayed till pupils are about 16 years old, in the Netherlands differentiation starts around the age of 14;
3. Compulsory subject choices. In Sweden and the Netherlands combinations of certain subjects are compulsory, even though these differ in both countries, whereas that is not the case in the US and the UK.

None of the above contrasts show a clear relationship with the ranking of the four countries according to general and sex-specific choices in STEM-degree courses. Thus the structural differences between the upper secondary education systems do not result in any evident contribution to explaining cross-national differences in this sense, in spite of what Bradley (2000) and Bradley and Charles (2004) suggested on the negative influences of differentiated secondary systems and systems with a high freedom of choice on female STEM participation.

5.8 Conclusions

At the beginning of this chapter we showed how certain western countries differ greatly from each other regarding the percentage of students who choose STEM courses compared to the student population as a whole and also in relation to the percentages of female students involved. The most direct preparatory route for a STEM degree course is to take maths and science subjects at upper secondary school level. It is likely that figures for these subjects at this level again vary among western countries but this cannot be demonstrated precisely because of the incomparability of the education systems.

In the in-depth study reported in the follow-up of this chapter, oral interviews were held in four western countries – Sweden, the UK, the US and the Netherlands – and reports and policy documents were studied in order to look at what social context characteristics in these countries influence the choosing of STEM degree course in general and female student choice in particular, and to what extent the choice of maths and science subjects in upper secondary education also plays a role.

Table 5.5 – Explanations for the ranking of the four countries regarding general STEM course choice

Ranking:	Distinguishing features
1. Sweden	many opportunities to make up for lost ground at government expense; at various points the STEM route is wide open for new intakes; high drop-out rate, but good financial support system for students; broad, interdisciplinary STEM courses (50% of time must be devoted to major subject)
2 UK	opportunities to make up for lost ground are limited and at own cost, so intake for the STEM route generally starts in upper secondary education; modest financial support system for students, but low drop-out rate; STEM studies begin broad or narrow according to preference
3. Netherlands	opportunities to make up for lost ground are limited and at own cost, so intake for the STEM route generally starts in upper secondary education; modest financial support system for students, coupled with medium drop-out rate; highly compartmentalized and instantly specializing studies
4. US	opportunities to make up for lost ground are limited and at own cost, so intake for the STEM route generally starts in upper secondary education; large differences between schools and states: pre-STEM education not equally accessible; medium drop-out rate, but poor financial support system for students; most STEM courses begin broadly, engineering however (lowest uptake in the US: see Table 5.1) specializes directly

The ranking of the four countries regarding general choices for STEM degree courses is as follows: the proportion of STEM students in relation to all higher education students is the highest in Sweden, followed by the UK, the Netherlands and the US. From the results of the in-depth study we conclude that at the heart of the explanation for this ranking lies the number of 'entry' points in different segments of the STEM pipeline, the costs of studying in relation to the drop-out risk, and the level of broad-based interdisciplinary studies as opposed to compartmentalization and early specialization. Table 5.5 illustrates the differences between the countries in this respect.

As far as the proportion of female STEM students is concerned, the ranking of the four countries is as follows Sweden again scored highest, followed by the US, the UK and the Netherlands The results of the in-depth study explain this ranking, which is based on labour market characteristics, social traditions and government policies Table 5 6 illustrates the relevant differences between the four countries

Table 5 6 – Explanations for the four countries regarding sex-specific choices for STEM degree courses

Ranking	Distinguishing features
1 Sweden	equal opportunity has been explicit policy and tradition for decades, good maternity and parental leave legislation, cheap subsidised childcare, 51% of couples with children work full-time
2 US	equal opportunity has been explicit policy and tradition for decades, poor maternity and parental leave legislation, expensive childcare, exact figures unknown, but most couples with children work full-time
3 UK	women in STEM sector a policy issue for around 10 years, modest maternity and parental leave legislation, expensive childcare, 25% of couples with children work full-time
4 Netherlands	low awareness of the position of women in policies and society, modest maternity and parental leave legislation, quite expensive childcare, 5% of couples with children work full-time

Our findings show that students considering a course of study decide in favour of STEM course the more a country's STEM education has entries at different points along the route, the drop-out risk coupled with the financial costs are acceptable, and the curriculum (and thus the number of future opportunities) is not restricted too much and too early For female students in particular, the choice of a STEM course is more attractive in western countries that are more gender conscious and advanced regarding women's emancipation and where it is more customary or necessary that mothers work full-time Despite the fact that maternity and parental leave as well as childcare provision can influence female participation in the STEM labour market, the US shows that a link to this is not necessarily the case

None of the structural differences between the upper secondary educational systems in themselves (broadness of curricula, extent of differentiation and compulsory subject choices as opposed to freedom of choice) contribute clearly to the explanation of cross-national differences in general or female STEM choice in higher education

This and other findings must be considered in the light of the limitations of our in-depth study, which was only exploratory. It would be interesting to extend our research and test our findings on a larger and more quantitative scale.

Notes Chapter 5

1. Unlike the European Commission (2004), for instance, we have excluded life sciences from the STEM courses and biology from the maths and science subjects because problems on the job market and women being underrepresented occur less in these courses and subjects.

2. The six respondents interviewed were working in London or Oxford. It was not always clear if the explanations they put forward applied to the UK in general or England in particular. Also, the school system in England, Wales and Northern Ireland is somewhat different from that in Scotland.

6 Exploring cross-national differences in gender gaps in education*

6.1 Abstract

Although the participation rates of females in Science, Technology, Engineering and Mathematics (or STEM) education is poor in most western countries, considerable differences across countries exist as well. This may be due to differences in the so-called gender achievement gaps, i.e. delays of one sex with respect to the other. The variation in gender gaps in mathematics, science and reading literacy, both across countries and across schools within countries, is explored in the present study using the PISA data. The results of multilevel analyses show the participation of women in tertiary STEM education to increase as the relative achievements of girls with respect to boys in secondary education improve. When the characteristics of schools and countries are examined in relation to the size of the gender achievement gaps, integrated educational systems are found to be more favourable to the achievement of girls than differentiated educational systems.

6.2 Introduction

In many western countries, a serious shortage of highly educated personnel in the area of Science, Technology, Engineering and Mathematics (or STEM) currently exists (Cervantes, 1999; CAWMSET, 2000; Roberts, 2002; Jordan & Yeomans, 2003; ROA, 2003). This problem could be largely solved if the participation of females in this sector rose to the same level as the participation of males. Despite the fact that large numbers of women in many western countries now participate in higher education, they nevertheless tend to choose the STEM sector much less frequently than men.

The observed imbalance is even more relevant in Europe where the European Council announced in 2000 that the region should become the most dynamic and competitive knowledge economy in the world within the next ten years. Several

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* A slightly different version of this chapter has been accepted for publication in Educational Research and Evaluation.

benchmarks - including reduction of the imbalance between men and women in the STEM sector - were identified to meet this objective (European Commission, 2002, 2003a, 2004)
In this chapter, one of the possible causes of the lack of participation of females in STEM fields was explored, namely their substantially lower levels of maths and science proficiency compared to males, while the opposite is true for language and reading (Johnson, 1996, Stephens et al , 2004) Using the PISA data, so-called gender achievement gaps were analyzed across countries and schools The correlations between the gender achievement gaps in secondary education and the STEM participation of women in tertiary education were examined along with those features of the secondary schools, educational systems and society in general which appear to be related to the observed gender achievement gaps

6.3 Background

6.3.1 International differences in STEM choices according to gender

The OECD (2003) collects statistics on the number of male and female graduates per field of tertiary study for different countries The percentages of 2001 graduates which were female for the different STEM fields have been calculated on the basis of this information and are presented in Table 6 1 (OECD, upon request) In the final column, the average of the previous columns is given, thus ignoring the fact that the absolute number of graduates in the fields of study is not equal

The underrepresentation of female graduates within the STEM fields of study is generally greatest for engineering, manufacturing, construction and computing and lowest for physical sciences, mathematics and statistics Rather remarkable are the considerable cross-national differences The highest means occur in the final column for Poland, Ireland, Italy and Spain while extremely low means occur across the board for the Netherlands and Switzerland

Table 6.1 – Percentages of tertiary ISCED-5A qualifications awarded to females in STEM fields of study in 2001. Source: OECD, upon request*

	Engineering, manufacturing & construction	Physical sciences	Mathematics & statistics	Computing	Mean
Australia	21.7	35.6	37.7	25.5	30.1
Austria	17.3	27.3	40.8	11.0	24.1
Belgium	20.4	35.1	45.5	16.3	29.3
Czech Republic	29.9	37.9	45.9	7.0	30.2
Denmark	22.5	35.4	45.0	19.2	30.5
Finland	19.4	45.4	39.1	33.9	34.5
France	23.8	37.5	43.3	19.2	30.9
Germany	20.5	28.0	44.1	12.1	26.2
Hungary	27.6	36.5	22.2	21.1	26.9
Iceland	21.2	53.5	20.0	19.4	28.5
Ireland	26.1	47.8	48.6	38.7	40.3
Israel	23.4	39.4	34.2	x	32.3
Italy	27.6	42.3	62.5	27.1	39.9
the Netherlands	12.4	25.7	26.9	14.0	19.8
New Zealand	31.7	n.a.	28.6	28.6	29.6
Norway	21.6	33.3	32.7	18.6	26.6
Poland	24.0	64.5	75.4	22.9	46.7
Spain	28.5	51.1	55.1	23.4	39.5
Sweden	27.8	43.0	35.9	40.1	36.7
Switzerland	12.1	21.6	22.0	12.4	17.0
United Kingdom	19.3	39.8	40.4	24.8	31.1
United States	21.4	38.2	45.3	29.2	33.5

* Including advanced research programmes

x: data included in column Mathematics & statistics; n.a.: not available

6.3.2 Gender achievement gaps in relation to differences in choices across countries

Studies of the choice of STEM subjects and STEM fields of study have shown various pupil, family, school and country factors to play a role (see, for an overview, van Langen & Dekkers, 2005a, 2005b; van Langen, Rekers-Mombarg & Dekkers, forthcoming). In this chapter, the influence of one factor in particular – namely, the relative differences in achievement of boys versus girls within the fields of maths, science and reading in relation to their choice of STEM fields of study – was explored in greater detail.

The importance of relative achievement differences was previously highlighted by Jonsson (1999), for example, who developed a rational choice model in which the selection of subjects is determined by a pupil's relative chances of success and the estimated utility and benefits of taking a particular subject (i.e., 'comparative advantage'). Uerz, Dekkers, Béguin and Dronkers (2004) similarly found the choices of pupils – after correction for such background characteristics as socio-economic status and immigrant status – to be related to their proficiency in language compared to maths.

Both Jonsson and Uerz et al. were concerned with intra-individual achievement differences. Within the context of the present study, however, we were interested in the role of relative differences at a higher level. In considerable national and cross-national research (Johnson, 1996), girls have been found to be ahead of boys in reading and language but to lag behind in maths and frequently also in science. While this also may explain the low levels of STEM participation for female pupils relative to male pupils, the figures in Table 6.1 show the STEM participation of women to also vary considerably across countries. The question which then arises is whether or not the cross-national differences in the STEM participation of females is – at least in part – due to relative differences in the achievement of girls with respect to boys across countries or a so-called 'gender achievement gaps.'

6.3.3 Gender achievement gaps and their explanation

Studies into (sex-specific) differences in achievement have been carried out on an even larger scale than studies into differences in subject choice, and in both types of research generally the same determinants at the levels of the pupil and the family are proposed. Presupposing an effect of the size of the gender achievement gaps on female STEM participation across schools and countries, however, most relevant would be to examine the characteristics of the schools, educational systems and society in general which can explain for these gaps.

In previous studies of the differences in the gender achievement gaps *across schools*, the effect of single-sex schools on the maths achievement of girls was considered. Daly (1996) could not demonstrate such an effect and therefore suggested that other studies on the topic may have failed to control sufficiently for differences in the socio-economic backgrounds of the school populations, differences in the school curricula or differences between schools in the private versus public sectors. Derks and Vermeersch (1999) have similarly pointed out that single-sex schools are often private schools and thus involve a different type of pupil than public schools. Still other studies of contextual explanations for the observed gender achievement gaps have been concentrated on the influence of intake and selection effects as a result of the organizational and instructional characteristics of the schools and teachers. Hallinan and Sorensen (1987), for example, report that boys are more likely to be placed in high-ability maths groups within a classroom than girls. Similarly, Fennema (1996) showed sex differences in maths achievement to strongly vary depending on social class and ethnicity but also on the school and teacher. In other research, Kristensen and Jenneskens (1985) found the maths achievement of girls to be higher in rural than in urban schools, which is partly in keeping with the results of a study by van Langen et al. (forthcoming) who found a higher degree of urbanization for the community in which a pre-university school is located to exert a significant negative effect on the choice of maths and science subjects by all pupils (i.e., girls *and* boys).

Baker and Jones (1993) examined the gender gap differences in the maths achievement of pupils *across countries* with the aid of the so-called SIMS data (i.e., Second International Mathematics Study of the achievement of 13-year old pupils in a number of western countries in 1982). The conclusion was that the sex differences in maths achievement were smaller in those countries with a more favourable 'women's status' – expressed as the percentage of females in higher education, the labour force in general and industrial work in particular. When these findings are related to the findings of van Langen and Dekkers (2005), the presupposed influence of gender achievement gaps on female STEM participation appears to be confirmed: In the latter qualitative country study, a relation was found between a high choice of STEM fields by females, on the one hand, and participation of women in the labour market, explicit government policy aimed at equal rights and opportunities for women and a social tradition of equality for men and women, on the other hand.
Bradley and Charles (2004) found an association between more differentiated, vocationally-oriented secondary educational systems versus comprehensive secondary educational systems and greater sex segregation across fields of study in tertiary education. As far as we know, however, the structure of educational systems in terms of their comprehensiveness has never been studied in relation to gender achievement gaps. It is nevertheless plausible that highly selective educational systems will lead to more marked differences in the proficiencies of pupils in general and male versus female pupils in particular.

6.3.4 Research questions

The varying gender achievement gaps in secondary education and the relations of these to female STEM participation in tertiary education were explored in the present study using the mathematics, science and reading literacy data from the PISA 2000 and PISA+ for 15-year-old pupils from 42 countries (OECD, 2001a; OECD/ UNESCO, 2003). The specific research questions were as follows:

1. To what extent can one speak of a gender gap in maths, science and reading literacy across schools and countries and, at the level of the country, is there a

relation between the size of the gender achievement gaps in secondary education and female STEM participation in tertiary education?
2 Are the observed gender achievement gaps associated with particular characteristics of the schools or countries?

6.4 Design of the study

6.4.1 Sample

Most of the data analyzed within the context of the present study stem from the PISA assessment studies, which were mainly carried out in 2000 and – for a smaller set of the countries or so-called PISA+ countries – 2001 Unlike many of the PISA reports, however, we also used the data from the Netherlands which did not meet the sampling criteria set by the OECD That is, the sampling criteria were considered less relevant for the study of the relations between different variables than for the estimation of proficiency levels

The data for a total of 8364 schools and 224,058 fifteen-year-old pupils from 42 countries in the PISA-2000 and PISA+ samples were thus analyzed The number of pupils in the mathematics and science literacy analyses was about half the number of pupils in the reading literacy analyses because all of the pupils took the reading literacy test and only half took the science literacy test and the other half the maths literacy test

It should be noted that a number of the characteristics of the PISA countries included in the present analyses do not stem from the PISA database itself but from the country comparisons conducted by the OECD and the United Nations

6.4.2 Variables

Pupil-level variables
The main variables of interest at this level were the *maths, science and reading literacy scores* of the pupils Given that the PISA followed a rotated design in which not each pupil performed the same tasks, five plausible values for each pupil's proficiency level, instead of just one proficiency score, were analyzed simultaneously per domain The average for this score across all countries was set at 500, with a standard deviation of 100 As the term 'literacy' indicates, the procedure used to assess – for instance – maths proficiency differed from the more straightforward procedures associated with – for example – the TIMSS (Third International Mathematics and Science Study) Within the context of the PISA,

mathematics literacy was defined as 'the ability of pupils to recognize and interpret mathematics problems encountered in their world, to translate these problems into a mathematical context, to use mathematical knowledge and procedures to solve the problems within their mathematical context, to interpret the results in terms of the original problem, to reflect upon the methods applied, and to formulate and communicate the outcomes' (OECD, 2001a, p.71). Similar types of definitions were used to assess science and reading literacy within the context of the PISA.

Sex (0 =males, 1=female), *immigrant status* (0=native, 1=both the child and his or her parents born elsewhere) and *socio-economic status* of the pupils were also coded. This latter variable was based on the occupations of the parents and calculated following a procedure developed by Ganzeboom, de Graaf and Treiman (1992). Whichever index was higher, either the index of the father or the mother, was used in the analyses.

School-level variables

Four variables at the level of the school were included in the analyses. *School type* encompassed three basic types of schools: government-independent private schools, government-dependent private schools, and public schools. Private schools are either controlled and managed by a non-governmental organization or the governing board consists of mostly members not selected by a public agency. A school is considered government-dependent when it receives 50% or more of its funding from government agencies. For the analyses, we used two dummy variables, in both of which public schools are coded as 0. *Urbanization* was used to indicate whether the school was located in a village (fewer than 3,000 people), a small town, a somewhat bigger town (at least 15,000 inhabitants), a city with more than 100,000 but less than a million inhabitants, in the centre of a city with more than a million people, or elsewhere in such a very big city. Two other aggregated analytic variables were also used, namely *average socio-economic status* for the school and *proportion of female pupils*.

Country-level variables

At the level of the country, the *country average socio-economic status* was included as a variable (i.e., aggregated across all pupils). An *index of the degree of integration for the national educational system* was also created in the following manner[1]. Nine indicators of integration were available: grade differentiation (i.e., the standard deviation for the grades the pupils in a particular country were in), track differentiation (i.e., a ratio-statistic describing the dispersion of pupils over the possibly existing various tracks: the higher the value for this statistic, the more comprehensive the system; the lower the value, the more differentiated the system)[2], the maximum number of tracks apparently existing within the educational system[3], socio-economic segregation (i.e., the differences between the schools within a country with respect to their average socio-economic statuses expressed in standard deviations), sex segregation (likewise), immigrant segregation (likewise), quality differences in maths literacy across schools (likewise), quality differences in science literacy across schools (likewise), and quality differences in reading literacy across schools (likewise)[4].

Having a score for each country on each indicator, a principal component analysis was conducted to look into the dimensionality. The immigrant segregation indicator did not load well on any of the original factors and was therefore dropped from the analyses. In Table 6.2, the loadings of the eight remaining indicators on a factor which accounts for 48% of the variance in the indicator scores and is labelled the integration-differentiation dimension are presented. The table also contains some descriptive statistics for the nine indicators. Appendix E contains the data matrix of the scores of each country on each indicator (Table E.1). The resulting scores for each country on the integration-differentation dimension will be presented in Figure 6.2 in the Results section[5].

Table 6.2 – Descriptive statistics and factor loadings for indicators of integration-differentiation

	Mean	S.D.	Min	Max	Factor loading
grade differentiation	0.53	0.26	0.00	1.16	0.39
track differentiation	0.71	0.20	0.37	1.00	-0.74
number of tracks	2 55	1.27	1.00	6.00	0 48
socio-economic segregation	7.87	1.43	3.73	11.15	0.42
gender segregation	0.21	0.07	0.09	0.41	0.46
immigrant segregation	0.07	0.06	0.00	0.28	n.a.
quality differences maths	51 88	13.37	21.53	74.76	0.92
quality differences reading	56.40	14.22	28.53	79.57	0.93
quality differences science	49.78	11.77	21.32	73.00	0 90

n.a.: not applicable

Three other variables at the level of the country were not derived from the PISA data. The first concerns the *percentage of female STEM graduates in tertiary type A-education per country* averaged across the four STEM fields of study as distinguished by the OECD. The results for this variable have already been presented in the final column of Table 6.1, where it can be seen that a value is available for only 22 of the 42 PISA countries. The two other variables come from the Human Development Report 2004 (UNDP, 2004). *Female economic activity rate* concerns the share of the female population that supplies or is available to supply labour for the production of goods and services. The *gender empowerment measure* is a composite index measuring gender equality along three basic dimensions: economic participation and decision-making, political participation and decision-making and power over economic resources. As can be seen from Table 6.3, a value on these latter two variables was also not available for all of the PISA countries. The missing values were replaced with the values from similar countries[6].

Table 6.3 – Indicators of women's status in PISA countries. Human Development Report 2004 (UNDP, 2004)

	female economic activity rate	gender empowerment index		female economic activity rate	gender empowerment index
Albania	74	n.a.	Italy	59	0.58
Argentina	48	0.65	Japan	68	0.53
Australia	78	0.81	Korea	71	0.38
Austria	66	0.77	Latvia	80	0.59
Belgium	67	0.81	Liechtenstein	n.a.	n.a
Brazil	52	n.a.	Luxembourg	58	n.a.
Bulgaria	86	0.53	Macedonia	72	0.52
Canada	83	0.79	Mexico	48	0.56
Chile	50	0.46	the Netherlands	67	0.82
Czech Republic	83	0.59	New Zealand	80	0.77
Denmark	84	0.85	Norway	85	0.91
Finland	87	0.82	Peru	44	0.52
France	77	n.a.	Poland	80	0.61
Germany	70	0.80	Portugal	72	0.64
Greece	59	0.52	Russian Federation	82	0.47
Hong Kong	65	n.a.	Spain	57	0.72
Hungary	72	0.53	Sweden	89	0.85
Iceland	83	0 82	Switzerland	66	0.77
Indonesia	68	n.a.	Thailand	85	0.46
Ireland	53	0.71	United Kingdom	75	0.70
Israel	69	0.61	United States	82	0.77

n.a.: not available

The unweighted descriptive statistics for the pupil-, school- and country-level variables used in the analyses are presented in Table 6.4.

Table 6 4 – Descriptive statistics for all variables used in the analyses (unweighted)

	N	Mean	S D	Min	Max
Pupil level					
reading plausible value*	224,058	479 35	108 86	-73 34	881 96
maths plausible value*	124,795	478 39	114 17	-168 47	868 54
science plausible value*	124,632	480 37	107 60	-48 22	895 49
sex (1=girl)	224,058	0 50	n a	n a	n a
socio-economic status	224,058	47 47	16 42	16 00	90 00
Immigrant status (1=imm)	224,058	0 04	n a	n a	n a
School level					
average socio-economic status	8,364	46 95	9 31	16 00	79 00
proportion of girls	8,364	0 50	0 22	0 00	1 00
urbanization	8,364	3 03	1 20	1 00	6 00
public	8,364	0 87	n a	n a	n a
private, government independent	8,364	0 05	n a	n a	n a
private, government dependent	8,364	0 08	n a	n a	n a
Country level					
average socio-economic status	42	46 66	4 58	33 23	53 95
differentiation of the educational system	42	0 00	1 00	-2 20	1 86
female economic activity rate	42	70 48	12 21	44 00	89 00
gender empowerment index	42	0 66	0 14	0 38	0 91
female enrolment in STEM courses	22	31 1	6 82	17 0	46 7

n a not applicable

* For the five plausible values per subject, the mean is taken as the mean of the five means, the S D as the mean of the five standard deviations, and the minimum or maximum as the minimum or maximum across all minima or maxima, respectively Plausible values are random draws from a normal distribution given the estimated proficiency level of a pupil, and therefore the results can have a negative value

6.4.3 Analysis details

We applied multilevel analyses, acknowledging the three-level character of the data, with pupils being nested in schools, and schools in their turn being nested in countries (Snijders & Bosker, 1999). The data were also weighted in such a manner that each country contributed equally to the analyses. In addition, within country weights were used to make sure that the sample was fully representative of the population in question Any data missing from a pupil file was replaced by the school average, and a missing-data dummy was also created to indicate whether a substitution had been made (=1) or the original score was used (=0). In all of the analyses, the missing data dummies were included as predictors, but we will not present the parameter estimates as these do not provide substantial information.

For each plausıble value for maths, scıence and readıng profıcıency, a multılevel regressıon equatıon and the varıance components were estımated, the resultıng parameter estımates were pooled usıng a standard procedure avaılable ın HLM5 (Raudenbush, Bryk & Congdon, 2003) Gıven that our prımary ınterest was ın gender achıevement gaps, we focused on the random sex slopes across schools and countrıes (cf Bosker & Snıjders, 2004)[7] These ındıcate whether schools wıthın countrıes dıffer ın gender gaps ın profıcıency respectıvely whether countrıes dıffer ın thıs respect In order to answer the fırst research questıon, we estımated the varıance ın the sex slopes across both schools and countrıes, and we also estımated the sex slope for each country separately as the country level Empırıcal Bayes resıdual of the general sex effect In order to answer the second research questıon, we ıncluded approprıate ınteractıon terms by whıch such gaps mıght be explaıned Gıven that we applıed models wıth random slopes, we centred all of the contınuous varıables around the grand mean (by subtractıng the grand mean), whıch facılıtated the ınterpretatıon of the effect estımates

Gıven the enormous sample sızes for both the pupıls and the schools, a sıgnıficance level of 0 001 was employed For the analyses at the level of the country, whıch ıncluded only 42 countrıes, a sıgnıficance level of 0 05 was employed

Wıth respect to the second part of the fırst research questıon (ı e , the relatıon between gender achıevement gaps and female STEM partıcıpatıon), we confined ourselves to sımple correlatıon analyses at the level of the country Thıs was done for two reasons Fırst, data on female enrolment ın STEM courses was only avaılable for a lımıted number of countrıes Second and most ımportantly, we assumed the causal orderıng to be gender dıfferences ın scıence, maths and readıng achıevement followed by dıfferences ın further course takıng Gıven that a country's average socıo-economıc status may be related to both gender achıevement gaps and female enrolment ın STEM courses, the partıal correlatıons were estımated

6.5 Results

6.5.1 Gender achievement gaps across schools and countries and their relation to female STEM participation

The ınıtıal analyses calculated across all of the PISA countrıes show gırls to generally lag behınd boys ın maths and scıence lıteracy even when socıo-economıc status and ımmıgrant status have been controlled for and the opposıte to be the case for readıng lıteracy In terms of standard effect sızes -0 139 for maths, -0 048 for scıence, and +0 217 for readıng lıteracy

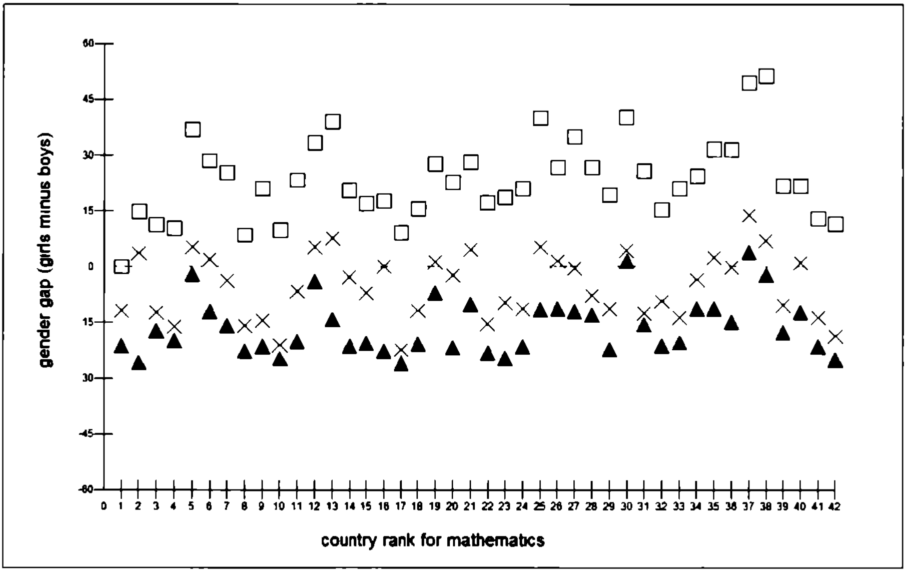
The next step in the analyses showed the size of the gender achievement gaps to vary considerably across countries and schools within countries for the three fields of study[8]. Sometimes the sign of the difference was even reversed – that is, sometimes the girls performed better than the boys, sometimes they performed worse.

The positions of the girls relative to the boys in the three fields of achievement for the different PISA countries are presented in Figure 6.1 where the countries are listed according to their international maths literacy rank. The results show the size of a country's gender gap in maths achievement to be separate from the country's level of general maths achievement. The lowest average maths score is attained in Peru while the highest average maths score is attained in the Netherlands while both countries show the maths achievement of girls to lag behind that of boys to an almost equal extent.

Only in New Zealand do girls achieve slightly better than boys in maths, but this result does not pass the critical significance test. One might actually say – just as for Albania, Thailand, Iceland and Finland – that the girls simply do not do better or worse than the boys in maths. The countries where girls lag most behind boys in maths are Brazil, Poland and the Netherlands although these countries do not – statistically speaking – differ from several other countries in this respect.
With regard to science literacy, girls do not significantly lag behind boys in most countries although they perform slightly worse on average. With respect to reading literacy, girls outperform boys in all countries except Peru.

The correlations between the relative achievement of the girls with respect to the boys for the three fields of achievement for each country were very high, from 0.76 for maths and science to 0.85 for maths and reading. This implies that in countries where girls lag less behind boys in maths and science, they also are more ahead of boys in reading.

Figure 6.1 – Gender gaps for three fields of achievement related to country's general maths rank



: reading; X: science; ▲: maths (width of 90%-confidence interval: app. 10 points)

1	Peru	15	Italy	29	France
2	Brazil	16	Portugal	30	Iceland
3	Indonesia	17	Poland	31	Denmark
4	Chile	18	Hungary	32	Belgium
5	Albania	19	Russian Federation	33	Switzerland
6	Argentina	20	Spain	34	United Kingdom
7	Macedonia, TFYR	21	United States	35	Canada
8	Mexico	22	Austria	36	Australia
9	Bulgaria	23	Germany	37	New Zealand
10	Israel	24	Czech Republic	38	Finland
11	Greece	25	Norway	39	Korea, Rep. of
12	Thailand	26	Ireland	40	Japan
13	Latvia	27	Sweden	41	Hong Kong, China (SAR)
14	Luxembourg	28	Liechtenstein	42	Netherlands

The correlations between the various gender achievement gaps in secondary education as estimated on the basis of the PISA data and the national participation rates for women in tertiary STEM courses (as shown in Table 6.1) were next calculated The estimates showed no significant correlations, even after we had partialled out a country's average socio-economic status Inspection of the data, however, showed two of the countries with data on female participation in tertiary STEM courses to have extremely outlying scores Poland and Israel Re-analysis of the data without these two countries and partialling the country's average socio-economic status out resulted in the following estimates for the relations between the relative achievement of girls with respect to boys in secondary education and a country's female STEM participation in tertiary education 0 52 (reading), 0 44 (maths) and 0 44 (science) An affirmative answer to our first research question thus appears to be the case An unfavourable position for girls with respect to boys in terms of achievement in secondary education is related to lower percentages of female students enrolling in tertiary education STEM courses This finding does not only relate to mathematics and science, implying that when girls do worse than boys in these areas they also participate less in STEM courses, but surprisingly also to reading This latter finding means that in countries where the advantage of girls over boys in the reading domain is more pronounced, girls also participate more in STEM courses

6.5.2 Explanations of varying gender achievement gaps across schools and countries

The results of the multilevel analyses in which we analyzed the roles of various pupil, school and country characteristics in the maths, science and reading literacy scores in greater detail are presented in Tables 6 5, 6 6 and 6 7 The first column of each table contains the parameter estimates for the main effects while the second column contains the parameter estimates for the interaction effects with sex The latter are of particular interest as they may contribute to the explanation of gender gap differences across countries and schools Nevertheless, the three tables will be considered in their entirety, including the information with regard to the different variance components at the bottom of each table

Maths literacy

With regard to the *main effects* for maths literacy, the results in Table 6 5 are more or less in keeping with our expectation – namely, that the maths achievement of boys, pupils from higher socio-economic milieus and non-immigrants is significantly higher than the maths achievement of girls, pupils from lower socio-economic milieus and immigrants, respectively The higher the average socio-economic status of the school, the higher the maths achievement in general Also, the pupils – both male and female – in schools where there are more girls tend to do better in maths When a school has 50% more female pupils, an increase of (28 5 × 0 50 =) 15 points is observed, which equals (15 / 100 =) 0 15 of a standard deviation for maths. And, finally, the pupils in a more differentiated educational system tend to have lower maths proficiency scores than the pupils in more integrated educational systems.

Table 6.5 – Results of multilevel analyses to explain variation in maths literacy; parameter estimates (with p-values in parentheses)

		Main effects	Interaction with sex
Intercept		485.757 (0.000)	
Pupil characteristics			
sex (0=boy, 1=girl)		-17.588 (0.000)	n.a.
socio-economic status		0.816 (0.000)	n.a.
Immigrant status (0=non-immigrant, 1=immigrant)		-26.109 (0.000)	n.a.
School characteristics			
school average socio-economic status		4.204 (0.000)	
Proportion of girls		28.453 (0.000)	
Proportion of immigrant pupils			
private government independent school vs. public			
private government dependent school vs. public			
Urbanization		-1.383 (0.222)	-2.339 (0.000)
Country characteristics			
country average socio-economic status			
differentiation of the educational system		-14.091 (0.040)	-5.270 (0.000)
female economic activity rate			
gender empowerment index			
Variance components			
Pupil level	a) intercept	5154.994 (0.000)	
School level	a) intercept	1713.606 (0.000)	
	b) sex slope	481 103 (0.000)	
	c) intercept – slope covariance	-345.225 (0.000)	
Country level	a) intercept	2858.828 (0.000)	
	b) sex slope	38.705 (0.000)	
	c) intercept – slope covariance	-39.629 (0.277)	

n.a.. not applicable

The only significant *interaction terms with sex* for maths literacy related to the degree of urbanization at the level of the school and differentiation of the educational system at the level of the country. As a consequence of the grand mean centering procedure, urbanization ran from -2 (i.e., a school in a small village) to +3

(i e , a school in the centre of a metropolis) with the estimated differences in proficiency levels for girls versus boys being -13 in villages and -21 in inner city schools Girls in rural areas thus show a smaller maths lag with respect to boys than elsewhere With respect to the differentiation of the country's educational system, the interaction boils down to the previously reported main effect of pupils in a differentiated educational system producing lower maths scores than pupils in a more integrated educational system being stronger for girls than for boys Girls thus tend to lag more behind boys with respect to maths literacy as the educational system in a country is more differentiated, which is a finding to which we will return below
Contrary to our expectations, none of the other school or country characteristics related to the gender gaps in maths literacy That is, the relevant interaction terms did not differ significantly from 0

With respect to the different *variance components*, the gender gaps co-vary with the intercept in the equation at the level of the school Given the negative sign, this shows the maths delay of girls with respect to boys to be somewhat smaller in schools where the pupils in general have a higher level of maths proficiency The same does not hold at the level of the country, however, as could also be seen in Figure 6 1

Science literacy
Table 6 6 contains the results of a similar analysis as conducted for science literacy, which highly resemble those for maths literacy The *main effects* are identical At the level of the pupil they encompass sex, socio-economic status and immigrant status, and at the level of the school the average socio-economic status and the proportion of girls And at the level of the country, the degree of differentiation for the educational system is significant

Furthermore, the *interaction terms with sex* again show girls in rural areas to lag less behind boys in science than girls in big cities and the effect of a more differentiated educational system to be more marked for girls than for boys with girls lagging more behind boys in countries with a more differentiated educational system than in countries with a more integrated system

Table 6 6 – Results of multılevel analyses to explaın varıatıon ın scıence lıteracy, parameter estimates (wıth p-values ın parentheses)

		Maın effects	Interactıon wıth sex
Intercept		481 941 (0 000)	
Pupıl characterıstıcs			
sex (0=boy, 1=gırl)		-6 751 (0 000)	n a
socıo-economıc status		0 806 (0 000)	n a
ımmıgrant status (0=non-ımmıgrant, 1=ımmıgrant)		-31 533 (0 000)	n a
School characterıstıcs			
school average socıo-economıc status		3 956 (0 000)	
proportıon of gırls		27 475 (0 000)	
proportıon of ımmıgrant pupıls			
pnvate govemment ındependent school vs publıc			
pnvate govemment dependent school vs publıc			
Urbanızatıon		-1 446 (0 145)	-2 382 (0 000)
Country characterıstıcs			
country average socıo-economıc status			
dıfferentıatıon of the educatıonal system		-11 592 (0 030)	-6 751 (0 001)
female economıc actıvıty rate			
gender empowerment ındex			
Varıance components			
Pupıl level	a) ıntercept	5236 107 (0 000)	
School level	a) ıntercept	1656 614 (0 000)	
	b) sex slope	543 794 (0 000)	
	c) ıntercept – slope covarıance	-421 373 (0 000)	
Country level	a) ıntercept	2114 234 (0 000)	
	b) sex slope	62 568 (0 000)	
	c) ıntercept – slope covarıance	-119 090 (0 041)	

n a not applıcable

Fınally, the *varıance components* (ı.e., the ıntercept-slope covarıance) agaın show the scıence achıevement of gırls wıth respect to boys to be more favourable ın schools where the pupıls generally have a higher level of scıence profıcıency. In contrast to the fındıngs for maths lıteracy, the same holds at the level of the country as well.

Readıng lıteracy

Table 6.7 contaıns the results of a sımılar analysıs for readıng lıteracy. Agaın, the results appear to be remarkably sımılar to those for maths and scıence lıteracy although they involve the girls showing a lead on boys with respect to reading literacy. The *main effects* show girls, pupils with a higher socio-economic status and non-immigrants to attain significantly higher reading scores than boys, pupils with a lower socio-economic status and immigrants respectively. Once again, the proportion of girls in the school is positively related to reading proficiency. Different than for maths and science literacy, however, the main effect of the degree of differentiation for the educational system was not significant for reading proficiency.

Table 6.7 – Results of multilevel analyses to explain variation in reading literacy; parameter estimates (with p-values in parentheses)

		Main effects	Interaction with sex
Intercept		465.385 (0.000)	
Pupil characteristics			
sex (0=boy, 1=girl)		22.678 (0.000)	n.a.
socio-economic status		0.859 (0.000)	n.a.
immigrant status (0=non-immigrant, 1=immigrant)		-32.600 (0.000)	n.a.
School characteristics			
school average socio-economic status		4.222 (0.000)	
proportion of girls		33.835 (0.000)	
proportion of immigrant pupils			
private government independent school vs public			
private government dependent school vs public			
Urbanization		-0.135 (0.899)	-2.784 (0.000)
Country characteristics			
country average socio-economic status			
differentiation of the educational system		-10.800 (0.082)	-4.900 (0.000)
female economic activity rate		0.360 (0.556)	0 365 (0.003)
gender empowerment index			
Variance components			
Pupil level	a) intercept	4736.253 (0.000)	
School level	a) intercept	1659.306 (0.000)	
	b) sex slope	312.470 (0.000)	
	c) intercept – slope covariance	-250.433 (0.000)	
Country level	a) intercept	1972.856 (0.000)	
	b) sex slope	55.709 (0.000)	
	c) intercept – slope covariance	-62.141 (0.136)	

n.a.: not applicable

The *interaction terms with sex* again show the relative position of girls with respect to boys to be more favourable in rural areas than in urban areas For reading literacy, this means that boys in rural areas show greater arrears with respect to girls than elsewhere While the main effect of the degree of differentiation for the educational system did not prove significant, the interaction with sex did: Countries with a more differentiated educational system again appeared to be less favourable for girls, which means – in this case – that the reading lead of girls over boys is greatest in countries with a more integrated educational system

A new finding is the relation of a country's female economic activity rate to the gender achievement gap. In countries where women are more economically active compared to countries where women are less economically active, girls are further ahead of boys with respect to reading literacy.

The *variance components* again show the gender gaps to co-vary negatively with the intercept in the equation at the level of the school. That is, the advantage of girls over boys with respect to reading literacy is significantly greater in schools where the pupils in general have a higher level of reading proficiency

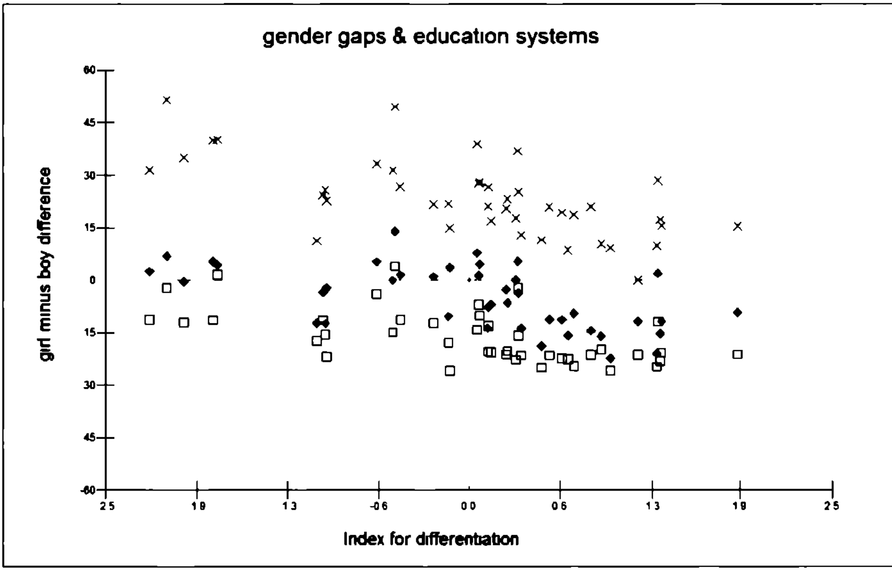
In both Tables 6.5 and 6.6 as well as in Table 6 7, the size of the sex slopes show considerable variability in the gender achievement gaps across both schools and countries to still exist While we attempted to explain the gender achievement gaps via the inclusion of interaction terms, a considerable portion of the variability in the gender achievement gaps for maths, science and reading literacy could not be explained

Interaction between sex and degree of differentiation

In Figure 6 2 the interaction effect between sex and the degree of differentiation of the educational system on proficiency levels is considered in greater detail In the figure, the gender achievement gaps for maths, reading and science literacy are plotted against an index of the degree of differentiation for a country's educational system.

On the left hand side of the figure, those countries with a non-selective, integrated education system and little or no segregation are represented. According to our index, Canada has the most integrated system with marginal quality differences between schools, little or no segregation with respect to socio-economic status or sex, a comprehensive system and almost all 15-year old pupils placed in the same grade Belgium, in contrast, has the most differentiated educational system in terms of both its structure and selection processes. For the gender achievement gaps in maths, science and reading literacy, the following general pattern can be seen to exist· The more integrated the educational system of the country, the smaller the gender gap for maths and science literacy (i.e., the less girls lag behind boys) and the larger the gender gap for reading proficiency (i.e., the greater the lead of girls over boys) In short: The relative position of girls with respect to boys is generally more favourable within such integrated systems.

Figure 6.2 – Gender gaps for three fields of achievement according to integration/differentiation of country's educational system



X: reading; ♦: science; □: maths

-2.20	Canada	-0.14	Korea, Rep. of	0.50	Netherlands
-2.08	Finland	-0.13	Brazil	0 55	Czech Republic
-1.96	Sweden	0.06	Latvia	0.64	France
-1.76	Norway	0.07	Russian Federation	0.68	Mexico
-1.74	Iceland	0.07	United States	0.72	Germany
-1.05	Indonesia	0.13	Switzerland	0.83	Bulgaria
-1.01	United Kingdom	0.14	Liechtenstein	0.90	Chile
-0.99	Denmark	0.15	Italy	0.96	Poland
-0.98	Spain	0.26	Luxembourg	1.15	Peru
-0.64	Thailand	0.27	Greece	1.28	Israel
-0.53	Australia	0.32	Portugal	1.28	Argentina
-0.51	New Zealand	0.34	Albania	1.30	Austria
-0.47	Ireland	0.34	Macedonia, TFYR	1 31	Hungary
-0.25	Japan	0.36	Hong Kong, China (SAR)	1.86	Belgium

Robustness of the findings

When presenting the initial results on the relation between participation of female students in STEM courses and gender related achievement gaps, we noticed that the results were sensitive for possible outliers. For that reason we reanalyzed the data as it was presented in Tables 6.5 through 6.7, but now for the 28 OECD countries only. The results of these analyses indicate remarkable robustness of the results: with respect to our focal point of interest – the cross level effects of country variables with gender on pupil achievement – the same effects, with approximately the same magnitude show up. The only differences found lay in the occurrence or disappearance of some main effects. For maths, urbanization has a negative main effect, and the negative main effect of differentiation of the educational system becomes insignificant. This latter finding also relates to both reading and science literacy, where, moreover, a negative main effect of the gender empowerment index shows up. For reading literacy, urbanization also has a negative main effect. But the negative interaction effects of differentiation of the education system and urbanization with gender on the three literacy domains stay intact in these analyses in which we focus on the OECD countries only, as does the positive interaction effect of female economic activity with gender on reading literacy.

6.6 Discussion

In the first part of this chapter we showed the participation of women in tertiary STEM education is generally low although countries differ drastically with regard to such. Poland, Ireland, Spain and Italy constitute positive exceptions with percentages reaching 40%. Switzerland and the Netherlands constitute negative exceptions with figures lower than 20%.

The analyses presented next using the data from PISA 2000 and PISA+ revealed a remarkable pattern: The national gender gaps for science, maths and reading literacy in secondary education were found to correlate highly with each other: In countries where girls lag less behind boys in maths and science, they also are more ahead of boys in reading. Conversely, in countries where boys lag less behind girls in reading they also are more ahead of girls in maths and science. There are countries where the maths literacy of girls does not lag behind that of boys at all (e.g., New Zealand, Iceland, Finland, Albania, Thailand) but – in keeping with the foregoing observation – the reading proficiency of the boys in these countries then lags considerably behind the reading proficiency of girls.

The analyses also revealed gender achievement gaps with regard to maths, science and reading literacy vary considerably across countries as well as across schools within countries. And the question is just how this finding relates to the underrepresentation of women in the tertiary STEM sector In the Netherlands, which was found to have the worst participation rate for women in tertiary STEM courses, a large gender achievement gap also exists for both maths and science literacy in secondary education The same holds for Austria In Sweden, Italy and Spain, however, the more favourable participation rates of women in tertiary STEM courses appear to be related to a significantly smaller gender achievement gap for science and a slightly smaller gender gap for maths when compared to the Netherlands or Austria

In order to identify the consistency of this pattern, the rank correlations were estimated between the participation rates for women in tertiary STEM courses and the relative achievements of girls with respect to boys in secondary education with the effect of a country's average socio-economic status partialled out High correlations varying from 0 44 to 0 52 were produced for the maths, science and reading gender gaps, which means that as the relative secondary achievement of girls with respect to boys improves, female tertiary STEM participation also improves Stated differently, the major underrepresentation of women in the tertiary STEM sector, as evident in the Netherlands, is associated with a major delay in the maths and science literacy of girls with respect to boys in secondary education This relative delay on the part of girls also appears to be more relevant for the non-choice of a tertiary STEM field of study than the high maths achievement of girls in absolute numbers in the Netherlands relative to other countries (see Figure 6 1)

Whether the same association holds at the level of the school or not cannot be determined on the basis of the present data Nevertheless, whether the girls in secondary schools with more favourable maths, science and reading achievement for girls relative to boys also tend to choose a tertiary STEM field of study relatively more often than girls in other types of schools is worth determining

In addition to documentation of the gender achievement gaps for different areas of literacy (i e , maths, science and reading) and different countries, it was attempted to explain the variation in the gender achievement gap across schools and countries In keeping with the earlier results of Kristensen and Jenneskens (1985, see section 6 3 3 above), girls were found to achieve relatively better in rural as opposed to urban schools That is, the delays of girls with respect to boys in the fields of maths and science literacy are smaller and their reading advantage larger when they attend a rural school When the pupils in a school have higher proficiency levels on average, moreover, the relative position of the girls also tends to be more favourable That is, the maths and science delays of girls with respect to boys decrease and the reading advantage of girls over boys increases under such circumstances The same holds at the level of the country but then for only science The science delays of girls with respect to boys are smaller in countries where the average levels of science proficiency are higher.

The results of our analyses further showed integrated educational systems to generally be more favourable to the achievement of girls relative to boys than differentiated educational systems. Stated differently: The more differentiated the educational system, the larger the mathematics and science arrears of girls relative to boys and the smaller the reading arrears of boys relative to girls. How should this finding be interpreted? A possible explanation, derived from social comparison theory, might be, that, since differentiated systems are tracked by definition, in such systems pupils of the same general ability level are homogenously grouped irrespective of their sex. On average then, achievement differences are small, and other aspects, like gender, may become the basis for social comparison, and typically this may lead to less self-confidence for girls. In an integrated system however, where achievement differences are more pronounced and are more likely to be the basic dimension for social comparison, the comparison turns out to be more favorable and will lead to more self-confidence for girls. In other words: In differentiated systems the more salient dimension for social comparison might be gender, while in integrated systems it might be achievement itself. That gender is indeed a crucial aspect in social comparison in the three domains studied here, is empirically demonstrated by Guimond and Roussel (2000). We presume that the alleged difference in self-confidence for girls in differentiated versus integrated educational systems is associated via some sort of self-fulfilling prophecy mechanism with differences in the size of the gender achievement gaps. However, whether this really is the explanation for the negative interaction effects of differentiation of the education system and gender or not, needs to be investigated further.

The established association between more differentiation in secondary education and larger sex segregation in tertiary education was not confirmed by the results of the qualitative country study conducted by van Langen and Dekkers (2005) but seems to fit the results of a study by Bradley and Charles (2004; see section 6.3.3 above). They posit a tendency for greater sex segregation across fields of study in countries characterized by curricular differentiated, vocationally-oriented secondary systems than in countries with comprehensive programs of secondary education. Their argument is twofold: First, highly (curricular) differentiated systems provide more opportunity for gender-differentiated choices and placements and second, they generally require that these choices are made during adolescence, when pressure to conform to sex-role stereotypes is particularly intense. However, most of the 15-years old pupils studied in PISA have not yet encountered the curricular differentiation in question. But when this type of differentiation occurs either at the end of the secondary or at the beginning of the tertiary cycle of the education system, when the choice for STEM courses has to be made, gender differences will certainly increase.

In conclusion, attempts should to made to close the gender achievement gap for maths and science literacy in secondary education in order to increase the STEM participation of women in tertiary education Our findings with regard to the influence of the degree of urbanization for a school are not of much policy use because this variable is a school context characteristics A more useful starting point may be the degree of integration/differentiation which characterizes a country's educational system

Notes Chapter 6

1 This procedure was inspired by a presentation from Ganzeboom at the 2002 Dutch Educational Sociology Conference, who presented country level information from the PISA data in a similar fashion It also follows the OECD procedures as used in Education Policy Analysis (OECD, 2001b) although the set of indicators actually used differs and most notably the track differentiation indicator In our study, all of the relevant data come from the PISA data files and no other information on the educational systems was used Grade differentiation indicates differentiation according to learning pace, which is a euphemism for grade repeating It is, however, only a proxy for this variable, since countries may differ in the formal age by which pupils enrol into education For that reason 15-year old pupils may be in different grades, although they have not repeated a grade The indices for the degree of differentiation created with, respectively without this grade differentiation indicator correlate 0 994, and the grade differentiation indicator has a factor loading of 0 394, which is an empirical argument to retain this indicator in the creation of the integration index selective systems apparently also have more differentiation according to learning pace

2 It was possible to determine which track a pupil was on from the pupil questionnaires Using this information, the population distribution across the six possible tracks was then calculated Given these estimates we estimate the mean percentage of pupils in each track (in case there are six tracks, this should be 16,66 percent), and thereafter the standard deviation This standard deviation is the ratio-statistic employed here

3 This information was derived from the principal questionnaire, which included a question on the number of tracks available within the school This is of course only a proxy for the real number of tracks available in an education system

4 The segregation indices were calculated directly from the data The three remaining indicators were estimated on the basis of the Empirical Bayes residuals from a multilevel analysis of the plausible values

5 Constructing an integration index on empirical material the way it is done in this study, has as a consequence that countries with more socio-economic diversity have a greater chance to have a more segregated and thus more differentiated education system

6 For the gender empowerment index the imputation was done as follows the missing data for Albania were imputed by using the numbers for Greece, Brazil by Argentine, France by Belgium, Hong Kong by Japan, Indonesia by Thailand, Liechtenstein by Switzerland, and Luxembourg by Germany For the female economic activity rate data were missing for Liechtenstein only, and these were imputed by using the numbers known for Switzerland In the end it turned out that the same results were found in the analyses using data with and without this imputations

7. Note that this analysis procedure uses all the data of all the countries at once. The weighting of the data is done in such a manner that each country contributes equally to the overall results. Moreover, in such an integrated multilevel analysis the gender gap for each country is estimated as a weighted average of the overall gender effect and the reliability weighted across school average gender effect. Consequently the results may differ somewhat from the figures presented in the OECD-reports.

8. The estimates of the variance components showed the effect sizes for reading and maths to be twice as big in some countries and, conversely, no differences between boys and girls in other countries. For science, the range ran from –0.22 to +0.12. Across schools within countries, the variability in the gender achievement gaps was even more marked.

7 Summary and conclusions

7.1 Introduction and theoretical background (Chapter 1)

In this thesis, a series of studies with, as the common underlying theme, the lagging participation of particular groups of pupils in maths and science education is reported on. Within the context of these studies, the observed lags are interpreted as a form of horizontal educational inequality. That is, the unequal distribution of social groups across educational options can be seen to produce unequal prospects for follow-up education and employment. In Chapter 1, an overarching theoretical framework for understanding this situation is presented.

Generally speaking, the educational inequality in the western world has decreased considerably over the past decades. The connections between pupil capacities and school success have increased and, as a result, the accessibility of education for different social groups. These developments are in keeping with the meritocratic educational ideal that school success should be a consequence of personal aptitude and accomplishment rather than the social and ethnic backgrounds or sex of pupils. At the same time, the latter set of connections has not disappeared altogether, which means that education still contributes to the so-called reproduction of social inequality: Already existing social inequalities are associated with educational inequalities which give rise, in turn, to new inequalities or reinforce already existing inequalities.

Over the years, a large amount of research has been conducted on the determinants of the subject and course choices of pupils and particularly their mathematics and science choices. The factors found to play a role can be placed within the aforementioned field of tension regarding the reproductive versus meritocratic calibre of education. An influence of such background characteristics as sex, social class, ethnic origin and various socio-cultural expressions of such on the choice of subjects and courses of study provides evidence for the reproductive function of education. An influence of pupil achievement, in contrast, is completely in keeping with a meritocratic line of thinking. Open to debate is whether the influence of such attitudinal characteristics as interest, motivation and effort should and can be viewed as meritocratic. Some experts are of the opinion that attitudinal characteristics are just as much a part of personal aptitude and accomplishment as capacity while others argue that attitudinal characteristics are also very much a product of socialization. With respect to the significant context characteristics at the level of the school and country, the legitimacy of their influence on the subject choices of pupils depends primarily on the question of whether their effects strengthen or neutralize the already reproductive effects of various social and cultural background factors; in the case of neutralization, a contribution is clearly made to the meritocratic calibre of education.

7.2 Group-related differences in the choice of mathematics and science subjects (Chapter 2)

Chapter 2 concerns the choice of maths and science subjects by pupils in the higher levels of secondary education in the Netherlands (i.e., HAVO and VWO) at a time when their choice of subjects was still relatively free – that is, prior to the introduction of the mandatory study profiles in 1998. The reported multilevel analyses were conducted on the data coming from the national VOCL'93 cohort for 2286 HAVO and VWO pupils.

The research described in Chapter 2 is explicitly aimed at evaluation of the reproductive versus meritocratic functions of Dutch secondary education with respect to at least the choice of maths and science subjects by HAVO and VWO pupils. The first research question was as follows.

- *To what extent do differences in the take-up of maths and science subjects, which cannot be traced back to differences in capacities and achievement, occur between groups of pupils in the higher levels of Dutch secondary education?*

Given equal levels of achievement, the results showed HAVO girls and HAVO pupils with low educated parents to choose fewer maths and science subjects than HAVO boys and HAVO pupils with high educated parents, respectively. For the VWO pupils, interactions occurred in the sense that the number of maths and science subjects chosen by VWO boys hardly depend on the parental level of education or ethnic origin. For the VWO girls, however, the picture is very different. Native Dutch VWO girls select very few maths and science subjects in the case of a low level of parental education but, in the case of a high level of parental education, the number of maths and science subjects greatly resembles the number for the VWO boys on average. The situation for minority VWO girls is the reverse of that for native Dutch VWO girls but less extreme: Minority VWO girls select more maths and science subjects in the case of a low level of parental education as opposed to a high level of parental education.
In the second part of the study reported on in Chapter 2, a number of other variables at the levels of the pupil, family and school levels and their contributions to the observed differences in subject choice were explored. The underlying research question was as follows.

- *Which other factors at pupil, family, and school levels that are related to individual capacities and merits on the one hand or to social or demographic group characteristics on the other hand appear to influence the observed choice differences?*

At the level of the school, only two variables were found to be related to the maths and science subject choice. First, a higher degree of urbanization for the community in which the school is located was negatively associated with the number of maths and science subjects chosen. Second, the VWO girls in schools where the grading committee plays, in principle, a role in the guidance of subject choice selected fewer maths and science subjects than the VWO girls in schools where this is not the case in principle. Characteristics of the family which appear to exert a limited but significant effect on the number of maths and science subjects selected by the HAVO and VWO pupils in general concern child-rearing style and for the VWO pupils, in particular, also parental level of educational aspiration for the child.

The majority of the pupil characteristics found to exert a significant effect – beyond the social-demographic background characteristics and pupil achievement – concerned the attitudes of the pupil. An orientation towards maths and science subjects and modern languages in the first year of secondary study, the pupil's enjoyment of maths and – for only the VWO pupils – Dutch language in the third year were significant predictors of the number of maths and science subjects chosen by the pupils. Also at the level of the pupil, the interaction between intrinsic/ extrinsic motivation for subject choice and sex was found to play a role. Girls with extrinsic motives were more likely to choose maths and science subjects than girls with intrinsic motives. For boys, the opposite was found to hold but to a weaker extent: Boys tend to choose fewer maths and science subjects when the motivation for their choice is extrinsic.

7.3 Sex-related differences in the determinants and process of mathematics and science choice in pre-university education (Chapter 3)

The research described in Chapter 3 initially addressed the same two questions as in Chapter 2 but then in a more detailed manner for only the 987 VWO pupils. The results of these analyses formed the basis for the supplemental analyses described in the second part of the chapter where the process side of maths and science subject choice is explored using path analyses. That is, the pupil and parent variables which were found to be significant in the first part of the study were causally ordered within a number of path analysis models. Given that the results of the earlier analyses showed the process of choosing maths and science subjects for VWO girls to proceed very differently than for VWO boys, special attention was also paid to this The supplemental questions addressed in Chapter 3 were as follows

- *What is the course of the causal relations between the pupil and family characteristics found to be significantly related to the choice of maths and science subjects?*

- *Do the causal models for the number of maths and science subjects chosen differ for boys versus girls?*

The modelling of the subject selection process resulted in three causal models one for all pupils and two for the boys and girls separately The models explained only about one third of the variance in the number of maths and science subjects chosen The causal models thus perform worse than the final regression model from the first part of the research reported on in Chapter 3, which was found to explain some 43% of the total variance Nevertheless, the causal models provide greater insight into the subject selection process, in general, and the differences between boys and girls, in particular Our results highlight the importance of viewing subject choice as a chronological process which also proceeds differently for boys and girls under the influence of different mediating variables A few of the variables only showed up in one or the other sex-specific causal model, and several sex-specific relations between the different variables were found Furthermore, the order of importance for the direct effects of different variables on the choice of maths and science subjects also proved sex specific The most striking conclusion stemming from the final causal model for all of the VWO pupils considered together is, that almost all the variance between boys and girls in the choice of mathematics and science subjects (93%) could be attributed to the direct relation between sex and the dependent variable Stated differently All of the indirect effects considered together exert only a very limited effect on the process of subject choice

7.4 Changes in mathematics and science choice following introduction of compulsory study profiles into Dutch secondary education (Chapter 4)

The research reported on in Chapter 4 largely resembles the research reported on in Chapter 2 An important difference, however, is that the HAVO and VWO pupils reported on in Chapter 4 were required to choose from four study profiles involving different but mandatory subject combinations while the pupils reported on in Chapter 2 still had considerable freedom of subject choice Quantitative analyses were performed on the data from the national VOCL'99 cohort for 3513 HAVO and VWO pupils

Of particular interest were the relations between the personal capacities of the HAVO and VWO pupils, on the one hand, and their background characteristics, on the other hand, as an explanation for the choice of a society profile, a science & health profile or a science & technology profile. The underlying research question was as follows.

- *How do the contributions of sex and social or ethnic background versus achievement to the choice of a science profile relate to each other since the introduction of the study profiles?*

- *What other factors at the levels of the pupil, family and school appear to influence the choice of a science profile?*

The results of the initial phase of the analyses showed the test scores from the first and third years of secondary school and the level of secondary education being followed in the fifth year (i.e., HAVO vs. VWO) to make the relatively greatest contributions to the degree of maths and science in the chosen study profile. In addition, the sex of the pupil and parental level of education (i.e., the highest level of education for the family) also made significant contributions: Boys and the children of high educated parents tend to choose a higher degree of maths and science in the study profile than girls and the children of low educated parents.
In the second phase of the analyses, the contributions of other possibly explanatory variables – after achievement, sex and parental level of education were taken into consideration – to the degree of maths and science in the chosen study profile were considered. A number of other variables are found to exert a significant effect and involve pupil attitudes (e.g., opinions regarding subjects and teachers, expectations for the future) and pupil aptitudes (e.g., learning style, report marks). Other significant variables concerned the recommendations of the parents and the school with regard to the choice of study profile.

The schools in the sample differed significantly in the average degree of maths and science in the study profiles which their pupils selected. And this was found to depend on the extent to which the school made explicit attempts to stimulate the choice of a science profile.

7.5 Cross-national differences in participating in tertiary science, technology, engineering and mathematics education (Chapter 5)

In Chapter 5, the results of an international comparative study of the possible explanations for cross-national differences in the STEM participation of higher education students are reported on. Inventory was first taken of the differences in

STEM participation for western countries in general but also for women in particular The results show the western countries to differ greatly from each other with respect to the percentage of students choosing a STEM course and the percentage of women doing this While the most direct preparatory route for a STEM degree course is to take maths and science subjects during secondary school and it is likely that the choice of these subjects also varies across western countries, such variation cannot be demonstrated due to the incomparability of the secondary education systems

The results of a subsequent in-depth study of four countries are next reported In Sweden, the UK, the US and the Netherlands, interviews were conducted with five or six experts and various reports and policy documents were studied The following question was addressed

- *How can differences in percentages between countries regarding the general and sex-specific choice of STEM courses in higher education be explained and to what extent does the choice of maths and science subjects in upper secondary education play a role?*

The proportion of STEM students relative to all students in higher education is the greatest for Sweden, followed by the UK, the Netherlands and the US The results of the in-depth study show the following factors to account for the observed differences the number of entry points for the different segments of the STEM pipeline, study costs in relation to the risk of early dropout and broad-based interdisciplinary study versus compartmentalization and early specialization

Sweden again scores highest with respect to the proportion of female STEM students followed by the US, the UK and the Netherlands The results of the in-depth study show the characteristics of the national employment market, social traditions and government policies to account for the rankings of the countries For female students, the choice of a STEM course is found to be more attractive in western countries which are more gender conscious and advanced with regard to women's liberation and where it is more customary or necessary for mothers to work full-time Maternity and parental leave as well as childcare arrangements can also influence female participation in the STEM labour market, but the US shows a link to this to not be necessarily the case

The secondary educational systems in the four countries studied in-depth differed structurally in several respects including broadness of the curricula, degree of differentiation, and mandatory subject choice as opposed to freedom of subject choice No one factor was found to clearly contribute to the explanation of the cross-national differences in STEM participation in general or by the females in higher education, however

7.6 Exploring cross-national differences in gender gaps in education (Chapter 6)

In the quantitative research providing the foundation for Chapter 6, an explanation was again sought for the cross-national differences in the participation of female students in higher education STEM courses. The observed cross-national differences were examined in connection with the size of the gender achievement gaps in secondary education or, in other words, the relative distance between the average levels of achievement for boys versus girls. Multilevel analyses were conducted on the data for 2000 and 2001 from the international comparative PISA study on the mathematics, science and reading literacy of 15-year old pupils. The analyses involved 224,058 pupils from 8364 secondary education schools in 42 countries.

Whether or not the size of the varying national gender achievement gaps in secondary education relates to female STEM participation in higher education, which also varies across countries, was examined. In addition, just which context characteristics appear to relate to the national gender achievement gaps was examined. And the extent to which the gender achievement gaps vary across schools within countries and the context characteristics related to such variation were explored. The following question was addressed.

- *To what extent can one speak of a gender gap in maths, science and reading literacy across schools and countries and, at the level of the country, is there a relation between the size of the gender achievement gaps in secondary education and female STEM participation in tertiary education?*

- *Are the observed gender achievement gaps associated with particular characteristics of the schools or countries?*

The initial analyses calculated across all of the PISA countries showed secondary school girls to generally lag behind secondary school boys in maths and science while the opposite is the case for reading literacy. Furthermore, the national gender gaps for science, maths and reading literacy are found to correlate highly with each other. In countries where girls lag less behind boys in maths and science, the girls are more ahead of boys in reading. Similarly, in countries where boys lag less behind girls in reading, they are more ahead in maths and science.

The results also showed the gender achievement gaps to vary considerably across countries. In our study, this finding is associated with the subsequent underrepresentation of women in the tertiary STEM sectors, which again differs drastically across countries (as also demonstrated in Chapter 5). As the secondary school achievement of girls relative to boys improves, female tertiary STEM participation also improves Stated differently, a major underrepresentation of women in the tertiary STEM sector is associated with a major gap in the maths and science literacy of girls with respect to boys in secondary education

It was next attempted to explain the variation in the secondary education gender achievement gaps across schools and countries Girls were found to achieve relatively better in rural as opposed to urban schools That is, the delays of girls with respect to boys in the fields of maths and science are smaller and their reading advantage larger when the pupils attend a rural school When the pupils in a school have a higher level of proficiency on average, moreover, the relative position of the girls also tends to be more favourable That is, the maths and science delays of girls with respect to boys decreases and the reading advantage of girls over boys increases under such circumstances The same holds at the level of the country but then for only science The science delays of girls with respect to boys are smaller in countries where the average levels of science proficiency are higher

The results of our analyses further showed integrated educational systems to generally be more favourable for the achievement of girls relative to boys The more differentiated the educational system, the larger the maths and science delays of girls relative to boys and the smaller the reading delays of boys relative to girls Finally, the gender achievement gap for reading literacy appeared to be related to the economic activity of the females in the country Girls tend to have a greater reading lead on boys in countries with a greater female rate of economic activity

7.7 Conclusions

Chapters 2, 3 and 4 of this dissertation were concerned with the determinants of the choice of maths and science subjects or a science profile by older and more recent samples of HAVO and VWO pupils in the Netherlands The research results show pupil aptitude and achievement to play an important role in their educational choices, which is clearly in keeping with the meritocratic assumption that the personal accomplishments of pupils should determine their school success However, both sex and social class (i e , parental level of education) were also found to play independent and significant roles in the maths and science choice in both samples This means that a reproductive component is still present in the upper levels of Dutch secondary education
The distinctions according to sex and social class appear to be even more marked for the relatively recent sample of secondary school pupils when compared to the older sample More specifically, the maths and science choices of the VWO boys in the more recent sample is influenced as well by parental level of education, which was previously not the case In addition, the option with the highest degree of maths and

science in the more recent sample (i e , the science & technology profile) was chosen by a much smaller percentage of the girls than the option with the highest degree of maths and science in the older sample (i e , the combined choice of chemistry, mathematics B and physics). At the same time, the effect of ethnic background observed for the older sample disappeared for the more recent sample, which suggests that the choice of subjects has become more meritocratic in this respect.

In the same chapters, which other variables – after control for the influences of social background, sex and achievement – appear to influence the choice of maths and science subjects or a science profile is considered The results with regard to the two samples resemble each other in so far as an important part of the variables found to play a significant role concern the attitudes of the pupils (e g , interest, motivation, evaluations of subjects and teachers, expectations for the future) When aptitude is interpreted in the broadest manner possible, which is certainly not acceptable to everyone, these attitudinal factors – in addition to achievement – can be seen to count as personal accomplishments and thus as legitimate determinants of school success And from such a perspective, the present findings provide evidence of the meritocratic quality of education as organized today For both samples, however, characteristics of the parents also influence the maths and science choice even after the influences of achievement and aptitude have been taken into consideration. Parental characteristics do not belong to the personal accomplishments of the individual pupil and therefore fail the meritocratic test The same holds for the differences in the process of subject choice of boys versus girls as detected in Chapter 3, for which the sex-stereotyped behaviour of the parents could be seen to provide a foundation

Those school characteristics which play a significant role in maths and science choice can strengthen or neutralize the reproductive effects of social-demographic background characteristics. In the analyses conducted on the older sample of pupils, an interaction effect was detected and found to boil down to VWO girls choosing fewer maths and science subjects when the grading committee played a role in advising with respect to subject choice This is clearly an example of a reproductive school effect, and sex-stereotypes discussions of the educational possibilities for the girls in question can be suspected to underlie this effect. For the more recent sample of pupils, no school effects related to a particular social group or the gender of the pupils occurred. The finding that pupils more frequently choose a science profile when the school explicitly stimulates this nevertheless shows how schools can contribute to better utilization of the personal aptitudes and capacities of pupils.

The results of the international comparative studies described in Chapters 5 and 6 show the conclusions with respect to the limited meritocratic calibre of Dutch upper secondary education to extend to tertiary education in the Netherlands and other western countries This is reflected in the widespread lags in the participation of women in STEM courses but also in the cross-national differences in the selection of STEM courses

The explanations for the cross-national differences found in the present studies can similarly be seen to involve either reinforcement or neutralization of the reproductive effects of other variables A society which is characterized by equal opportunity policies, good maternity care and parental leave, adequate child-care arrangements and the fully fledged participation of women in the employment market indeed appears to realize a more meritocratic choice of study When the aforementioned characteristics are missing either completely or in part, role reinforcement and thereby the promotion of a reproductive effect appears to occur In general, the STEM capacities of pupils also appear to be better utilized in countries where the education system is characterized by more entry points for the STEM pipeline, a favourable ratio between dropout rates and study costs and a broad, interdisciplinary set up of the different directions for study

The explanation for the differences in female STEM participation in tertiary education on the basis of the size of the gender achievement gaps in secondary education appears to be in line with a meritocratic line of thinking That is, personal aptitude and individual achievement appear to lie at the base of such gaps However, it is not the absolute but rather the relative achievement with respect to the other sex which plays a role Moreover, the gender achievement gaps clearly relate to such other context characteristics as degree of urbanization and the degree of differentiation in the education system – variables which have nothing to do with the personal accomplishments of pupils

In conformance with the research described in this thesis, it can be concluded that the maths and science choice processes for HAVO and VWO pupils in the Netherlands but also for higher education students in the Netherlands and other western countries do not proceed in a completely meritocratic manner A clear relation still exists between the background characteristics of the pupils and students, on the one hand, and the extent to which they choose maths and science subjects and STEM studies, on the other hand As a consequence, the social inequality within the STEM sectors continues to be reproduced at least in part via education Furthermore, optimal use is currently not being made of the available maths and science talent in the countries studied

Schools and countries clearly differ in the extent to which they reinforce or neutralize the aforementioned relations Viewed from a policy perspective, there is thus room for improvement in the sense that the general and group-specific participation in maths and science education can certainly be expanded For schools, from such a perspective, it is therefore recommended that attention be paid to the changing of pupil and parental attitudes. At the national and international levels, careful consideration of the characteristics of the education systems and the relevant social contexts for the creation of the conditions necessary to promote STEM courses is recommended.

On account of the present findings, various directions for future research can be identified. Specifically within the Netherlands, fundamental research is needed to understand the motives of girls to not select a science and technology profile despite high maths achievement and report marks. The question is whether the same socialization mechanisms are involved as in the explanation of why female employees, despite comparable qualifications and qualities, do not end up in as many higher – often management – functions as their male colleagues. Which educational structures or curricular adjustments can be seen to promote greater maths and science choices on the part of the aforementioned girls? The same holds, of course, for HAVO and VWO pupils with low educated parents as such pupils have also been found to select a science profile less frequently than might be expected on the basis of their achievement. In addition to the above, there is a considerable need for more information on the course of the transition from Dutch secondary to Dutch tertiary education and tertiary STEM education in particular for pupils with different study profiles. What are the consequences of the initial gap for students with a secondary science and health profile proceeding to a tertiary STEM course with respect to their fellow students with a secondary science and technology profile? Do such students experience marked delays or encounter major obstacles as a result of their overly 'light' profile selection in secondary school or are their capacities at the start of their profile study sufficiently predictive of the success of their tertiary STEM education? All of the preceding questions can and should be studied from an international perspective as well. For the time being, however, we are still confronted by the incomparability of the different education systems and particularly the secondary levels of education. And in order to get a better grip on the situation, new sources of information and possibly other research routes will have to be pursued.

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Appendices

Appendix A

Multicategorical response models

For these models, access to two levels of data (pupils within schools) is assumed and the outcome variable is treated as a vector of cumulative proportions (γ) with 4 categories in Chapter 2 and 3, and 3 categories in Chapter 4 (Goldstein, 1995). The vector γ can vary across pupils i and across schools j, which explains the subscript ij. The underlying logit "link" function for a response category (s) is as follows.

$$\gamma_{ij}^{(s)} = 1/(1+e^{-(\beta_0^{(s)}+\beta_1 x_{1ij}+u_{0j}^{(s)})})$$

In this example, one can speak of an intercept (β_0) and only one explanatory variable x_1 which can vary across pupils and schools. At the school level (j), there is a random effect u_{0j}. The coefficient β_1 is usually estimated with a negative sign, just as the coefficients for the other explanatory variables. This means that a higher value for the explanatory variable is associated with the choice of more maths and science subjects (Chapter 2 and 3) or with a higher degree of maths and science in the study profile chosen (Chapter 4). In Tables 2.2, 2.4, 3.2, 4.1 and 4.2, we have reversed the signs to make for greater readability. We have also, for this reason, omitted the parameter estimates for the maths and science subjects variables (Chapter 2 and 3) and study profile variables (Chapter 4) from these tables. They are now reported below (Table A.1 and A.2). The direction of the effects has again been reversed.

Table A.1 – Parameter estimates, estimates Model 1 and final model Chapter 2 and 3

	Model 1 (Table 2.2/3.2)		Final model (Table 2.4/3.2)	
	HAVO	VWO	HAVO	VWO
0 m&s subjects	-4.307 (0.475)**	-6.575 (0.710)**	-7.454 (0.757)**	-10.470 (1.152)**
1 m&s subject	-5.064 (0.481)**	-7.218 (0.716)**	-8.298 (0.764)**	-11.220 (1.160)**
2 m&s subjects	-6.001 (0.490)**	-8 195 (0.726)**	-9.320 (0.773)**	-12.350 (1.171)**

** = sign. p<0.01

Table A.2 - Parameter estimates Model 1 and final model Chapter 4

	Model 1 (Table 4.1)	Final model (Table 4.2)
Society profile	-0.625 (0.069)***	-1.218 (0.083)***
Science & health profile	-1.962 (0.078)***	-4.229 (0.125)***

*** = sign. p<0.001

The proportion variance explained (R^2) for the ordered multicategorical response models was calculated as the relation between the variance for the "fixed" part of the model (also called the linear predictor, σ^2_F) and the sum of the variance for the linear predictor, the variance at school level (τ^2_0), and the variance at the pupil level (σ^2_R) (Snijders & Bosker, 1999, pp. 233). The formula is as follows.

$$R^2 = \frac{\sigma_F^2}{\sigma_F^2 + \tau_0^2 + \sigma_R^2}$$

Appendix B

Description of the variables in the final model in Chapter 2 and 3

Table B.1 - Variables in the final model; mean (standard error) or percentages

Variables at pupil and family level	HAVO n=1299	VWO n=987
Number of maths and science subjects chosen		
% 1 subject	14.5	13.6
% 2 subjects	12.6	18.1
% 3 subjects	13.7	24.2
Sex: % boys	42.5	46.6
Parental level of education (2-6)	4.3 (0.9)	4.6 (1.0)
Ethnicity: % minority	6.3	8.2
IQ score (0-80)	52.1 (10.0)	56.0 (11.0)
Maths score (0-100)	62.4 (17.4)	75.5 (14.7)
Maths enjoyment (1=unpleasant, 4=really nice)	2.5 (0.9)	2.7 (0.9)
Dutch language enjoyment (1=unpleasant, 4=really nice)	2.4 (0.8)	2.3 (0.8)
Maths/science orientation (1-5)	3.5 (0.7)	3.7 (0.7)
Language orientation (1-5)	4.0 (0.8)	4.2 (0.7)
Motivation of subject choice: % extrinsic	48.6	40.8
Child rearing style: Autonomy granted (1-5)	3.4 (0.6)	3.5 (0.6)
Parental level of aspiration for child (1-8)	4.8 (1.3)	5.7 (1.3)
Variables at school level	**n=63**	**n=55**
Degree of urbanization for community (1-5)	3.5 (0.9)	3.5 (0.9)
Involvement of grading committee: % yes	64.4	63.5

Appendix C

Description of the variables in the final model in Chapter 4

Table C.1 - Variables in final model; means or percentages, standard deviations

Variables at level of pupil	Mean, %	SD
Profile chosen:		
% economics & society profile or culture & society profile	62.6	
% science & health profile	21.4	
% science & technology profile	16.0	
Sex: % boys	46.3	
Highest education for family (2-7)	4.6	1.0
Level of secondary education: % VWO	46.9	
Language score year 1 (0-1)	0.8	0.1
Maths score year 1 (0-1)	0.8	0.1
Maths score year 3 (0-100)	69.7	14.5
Maths enjoyment(1=dislike, 4=really like)	2.5	0.9
Importance modern foreign languages (1=unimportant, 4=very important.)	2.5	0.6
Importance maths and science subjects (idem)	2.6	0.9
Utility of physics for own future (1=not true, 3=true)	1.8	0.8
Pupil competent according to economics teacher (idem)	2.2	0.5
Report marks maths and science year 3 (1-10)	6.7	1.0
Science/technical profession desired (1=does not apply, 4=very applicable)	2.0	0.8
Concrete learning strategy (1=never use, 5=always use)	2.8	0.8
School recommendation (average of teachers, study adviser and guidance counsellor) regarding sc & t profile (-1=not recommended, 1=recommended)	-0.1	0.5

	% not recommended	% neutral	% recommended
Parental recommendations economics & society profile	10.8	50.5	38.7
Parental recommendations science & health profile	25.0	46.5	28.5
Parental recommendations science & technology profile	31.2	46.8	22.0
	% not suited	% neutral	% suited
Physics (entire curriculum) suited as final examination subject for pupil according to parents	40 3	20.5	39.3

Variables at level of school	Mean, %	SD
School policy with regard to choice of profile:		
% stimulate selection of science profile as much as possible	6.2	
% even distribution across 4 profiles	2.8	
% science profile for only those who can handle it	15.8	
% as little steering as possible	75 2	
Importance of choosing profile with most follow-up possibilities (1=most important, 5=least important)	3 9	0.6

Appendix D

Maths and science subject choices in the four countries studied in Chapter 5

In Table D.1 the collected statistics are presented on the maths and science subject choices in upper secondary education from the four countries involved in the in-depth study in Chapter 5. The table contains two lines of information per country: the first (g: G) gives the percentage of girls choosing or passing a subject compared to the total number of girls at the same educational level, the second line (b: B) gives the same for boys.

Table D.1 - Degree of participation in maths and science subjects/programmes in higher secondary education (ISCED level 3A; US: ISCED level 3) in the Netherlands, Sweden, UK (England) and the US by sex

Netherlands	Maths B		Physics		Chemistry	
g: G	28		27		26	
b: B	48		47		46	
Sweden	Natural science programme					
g: G	19					
b: B	27					
UK (England)	Maths		Physics		Chemistry	
g: G	13		4		12	
b: B	26		17		13	
US	Maths adv. academic level I	Maths adv. academic level II	Maths adv. academic level III	Chemistry I or physics I	Chemistry I and physics I	Chemistry II or physics II or adv. biology
g: G	16	15	12	33	15	16
b: B	13	15	12	27	18	14

Explanation Table D.1 per country

Netherlands. The figures relate to all pupils who did their final *Hoger Algemeen Voortgezet onderwijs* [Senior general secondary education] (HAVO) or *Voorbereidend Wetenschappelijk Onderwijs* [Pre-university education] (VWO) (both ISCED level 3A) exams in the subjects mentioned in 2002 (Central Finances Institutions (CFI), on request). Since 1998 most subjects offered have two levels (partial or entire curriculum). In Table D.1 these are combined since a final pass in a lower level is sufficient to be admitted on an undergraduate STEM course. The Dutch education system distinguishes between two mathematics options: Maths A is less in-depth than maths B (which is also indicated as pure maths) and provides considerably less access to higher STEM education.

Sweden. All pupils in higher secondary education follow a basic curriculum of eight core subjects including maths and (natural) science. In addition, they can choose from 16 national programmes or for an individually formulated course of study (all at ISCED level 3A). Only the percentages for the pupils taking the natural science programme in 1999 are reported in Table D.1 (Skolverket, 2000). This is one of two programmes (the other being social science) that give the most direct preparation for higher education.

UK: England. The percentages pertain to those pupils in England who have taken GCE A Level (ISCED level 3A) exams for different subjects in 2002–2003 as a proportion of all A Level candidates in the same year (DfES, 2004; only figures for England available on the website). In Table D.1 various maths options (e.g., statistics, pure maths) have been combined.

US. The percentages represent the highest level of maths and science courses completed by US high school graduates in 1998 (NCES, 2002). Only the advanced academic levels are included because American universities draw up their admissions criteria based on these. The highest level of maths and science in Table D.1 includes AP courses.

Appendix E

Datamatrix of the integration index indicators in Chapter 6

Table E.1 contains a datamatrix of the scores of each country on each indicator of the integration index in Chapter 6.

Table E.1. Scores for each country on the nine indicators originally used to create the integration index.

	grade differentiation	track differentiation	number of tracks	socio-economic segregation	gender segregation	immigrant segregation	quality differences maths	quality differences reading	quality differences science
Albania	0 52	0 580	3	8 510	0 220	0 020	55 85	61 51	47 29
Argentina	0 69	0 690	2	11 150	0 210	0 020	74 76	74 40	64 41
Australia	0 47	0 830	6	7 840	0 220	0 130	36 27	43 58	37 34
Austria	0 61	0 370	4	8 150	0 320	0 190	60 43	71 42	59 59
Belgium	0 59	0 470	5	8 750	0 270	0 080	71 40	79 21	73 00
Brazil	0 90	0 840	2	10 380	0 160	0 010	50 95	52 88	43 39
Bulgaria	0 46	0 670	2	7 720	0 270	0 020	69 76	75 44	56 88
Canada	0 48	1 000	1	7 220	0 140	0 120	21 53	28 53	21 32
Chile	0 74	0 620	3	9 920	0 260	0 010	60 14	67 10	55 78
Czech Rep	0 55	0 520	3	7 010	0 260	0 020	56 94	64 91	53 13
Denmark	0 28	0 960	2	7 270	0 140	0 070	40 49	48 14	44 86
Finland	0 32	1 000	1	6 610	0 090	0 030	26 97	34 00	27 23
France	0 69	0 670	3	8 570	0 180	0 040	56 92	62 33	64 84
Germany	0 63	0 900	2	7 830	0 170	0 130	68 16	79 57	64 58
Greece	0 46	1 000	1	9 200	0 180	0 130	70 10	68 29	56 73
Hong Kong	0 89	0 700	4	5 160	0 230	0 100	60 12	57 16	53 76
Hungary	0 59	0 550	3	9 440	0 300	0 030	64 50	73 36	65 36
Iceland	0 00	1 000	1	7 970	0 170	0 030	32 52	34 17	33 84
Indonesia	0 91	1 000	1	9 220	0 190	0 010	39 20	39 59	33 42
Ireland	0 84	0 670	3	6 300	0 360	0 030	32 45	41 81	39 49
Israel	0 36	0 450	4	9 320	0 280	0 130	68 28	66 87	62 65
Italy	0 52	1 000	1	8 230	0 290	0 110	55 44	66 56	59 27
Japan	0 00	0 630	1	3 730	0 280	0 010	57 30	56 74	56 59
Korea	0 13	0 460	1	7 150	0 410	0 000	50 39	41 43	46 79
Latvia	0 73	0 770	3	7 290	0 180	0 280	54 39	57 26	51 06
Liechtenstein	0 47	0 720	3	6 490	0 120	0 160	55 67	62 10	60 56
Luxembourg	0 70	0 520	4	7 520	0 210	0 110	47 05	56 30	49 04

	grade differentiation	track differentiation	number of tracks	socio-economic segregation	gender segregation	immigrant segregation	quality differences maths	quality differences reading	quality differences science
Mexico	0 79	0 400	4	10 310	0 180	0 060	52 80	60 12	46 02
Netherlands	0 60	0 510	2	6 730	0 140	0 070	60 73	62 32	63 95
New Zealand	0 35	0 790	2	6 820	0 300	0 140	44 92	46 28	45 70
Norway	0 11	1 000	1	5 920	0 130	0 060	34 06	38 35	36 55
Peru	1 16	0 650	2	9 630	0 260	0 010	64 84	78 44	53 50
Poland	0 00	0 390	1	7 940	0 280	0 010	69 58	74 65	63 32
Portugal	0 95	0 440	4	8 000	0 110	0 030	48 89	57 69	47 25
Russian Fed	0 50	0 540	3	7 130	0 180	0 050	55 54	52 61	48 83
Spain	0 50	0 970	3	8 810	0 140	0 040	38 51	38 82	40 49
Sweden	0 15	1 000	1	6 590	0 120	0 120	31 75	32 43	31 15
Switzerland	0 50	0 800	4	8 070	0 190	0 170	51 87	60 29	51 62
Thailand	0 54	0 740	2	8 580	0 180	0 000	44 95	42 44	39 42
Macedonia	0 48	0 530	4	7 670	0 220	0 140	52 69	61 23	47 24
UK	0 53	0 830	2	7 240	0 230	0 040	34 67	41 30	36 73
US	0 55	0 710	3	7 250	0 120	0 110	55 40	57 32	56 84

Samenvatting
(Summary in Dutch)

1. Introductie en theoretische achtergrond (Hoofdstuk 1)

In dit proefschrift is verslag gedaan van een reeks onderzoeken met als gemeenschappelijk thema de achterblijvende deelname van bepaalde groepen leerlingen aan de exacte vakken en studierichtingen In de onderzoeken is dit verschijnsel steeds opgevat als een vorm van horizontale onderwijsongelijkheid, de ongelijke verdeling van maatschappelijke groepen over de onderwijsrichtingen heeft immers ongelijke perspectieven op vervolgonderwijs en de arbeidsmarkt tot gevolg In hoofdstuk 1 is dit theoretisch kader globaal uitgewerkt

Over het algemeen is de onderwijsongelijkheid in de Westerse wereld beduidend kleiner geworden in de afgelopen decennia De samenhang tussen capaciteiten van leerlingen en hun schoolsucces is toegenomen en daarmee ook de toegankelijkheid van het onderwijs voor verschillende maatschappelijke groepen Dat is conform het meritocratisch onderwijsideaal dat onderwijssucces het gevolg moet zijn van persoonlijke bekwaamheden van leerlingen en niet gekoppeld is aan hun sociale of etnische herkomst en sekse Tegelijkertijd is laatstgenoemde koppeling nog steeds niet geheel uitgebannen, waardoor het onderwijs ten dele ook nog bijdraagt aan de reproductie van de bestaande maatschappelijke ongelijkheid

In de loop der jaren is een grote hoeveelheid onderzoek uitgevoerd naar de determinanten van de (exacte) vakken- en studiekeuzen van leerlingen De aangedragen factoren kunnen worden geplaatst binnen het bovengenoemde spanningsveld van de reproductiefunctie versus het meritocratisch gehalte van het onderwijs De invloed van achtergrondkenmerken zoals sekse, sociaal en etnisch milieu of sociaal-culturele uitingsvormen daarvan op de vakkenkeuze zijn een bewijs van het reproducerende gehalte van het onderwijs Daarentegen is de invloed van prestaties en capaciteiten geheel in overeenstemming met de meritocratische gedachte Het staat ter discussie of de invloed van atittudekenmerken van leerlingen, zoals hun belangstelling en inzet, gezien moet worden als meritocratisch Sommigen menen dat dergelijke kenmerken eveneens behoren tot de persoonlijke verdiensten van leerlingen, anderen wijzen erop dat dergelijke factoren mede het resultaat zijn van socialisatie Wat contextkenmerken op het niveau van school en land betreft, is de legitimiteit van hun invloed op de vakken- en studiekeuze vooral afhankelijk van de vraag of zij de reproducerende effecten van sociale en culturele achtergrondfactoren versterken of neutraliseren, in het laatste geval dragen zij bij aan het meritocratisch gehalte van het onderwijs

2. Groepsgebonden verschillen in de keuze van exacte vakken (Hoofdstuk 2)

Hoofdstuk 2 had betrekking op de exacte vakkenkeuze door leerlingen in het HAVO en VWO in Nederland in de tijd dat die keuze nog relatief vrij was, dus voor de invoering van verplichte profielen in 1998 De multilevel analyses waarover is gerapporteerd, zijn uitgevoerd op de data van 2286 leerlingen in HAVO en VWO, afkomstig uit het landelijke cohort VOCL'93 In dit cohort zijn leerlingen gevolgd die in schooljaar 1993/1994 in het eerste leerjaar van het voortgezet onderwijs zaten

Het onderzoek in hoofdstuk 2 was expliciet gericht op het toetsen van de reproductiefunctie versus het meritocratische gehalte van het voortgezet onderwijs, althans voor zover het de exacte vakkenkeuze van leerlingen in HAVO en VWO betrof De eerste onderzoeksvraag luidde

- *In hoeverre treden er verschillen op tussen naar sekse, sociaal milieu en etniciteit onderscheiden groepen leerlingen in HAVO en VWO ten aanzien van hun keuze voor de exacte vakken, die niet terug te voeren zijn op verschillen in capaciteiten en prestaties?*

Uit de resultaten bleek dat, bij gelijke prestaties, HAVO-meisjes en HAVO-leerlingen met laag opgeleide ouders minder exacte vakken kozen dan respectievelijk HAVO-jongens en HAVO-leerlingen met hoog opgeleide ouders Bij VWO-leerlingen traden interacties op in die zin dat de exacte vakkenkeuze van jongens niet werd beinvloed door hun etnische of sociale achtergrond, terwijl deze kenmerken bij de meisjes wel van invloed waren autochtone VWO-meisjes met hoog opgeleide ouders kozen ongeveer evenveel exacte vakken als VWO-jongens in het algemeen, terwijl autochtone VWO-meisjes met laag opgeleide ouders nauwelijks exact kozen Allochtone VWO-meisjes kozen juist exacter naarmate hun ouders lager opgeleid waren

In het tweede deel van de studie waarover in hoofdstuk 2 is gerapporteerd, is nagegaan welke overige leerling-, gezins- en schoolvariabelen nog van invloed waren op de exacte vakkenkeuze De achterliggende onderzoeksvraag luidde als volgt

- *Welke overige factoren op leerling-, gezins- en schoolniveau zijn van invloed op de geconstateerde keuzeverschillen, en in hoeverre vormen zij een aanvullend bewijs voor het meritocratische of juist reproducerende karakter van het onderwijs?*

Op het niveau van de school bleken slechts twee variabelen een bijdrage te leveren Een hogere urbanisatiegraad van de vestigingsgemeente hing negatief samen met het

aantal gekozen exacte vakken. Ten tweede bleek dat VWO-meisjes op scholen waar de rapportvergadering een rol speelde in de keuze-advisering, minder exact kozen dan VWO-meisjes op scholen waar dat niet zo was. Kenmerken van het gezin die een beperkt significant effect bleken te hebben op het aantal gekozen exacte vakken, betroffen de opvoedingsstijl – de mate waarin de ouders hun kind autonomie boden - en bij VWO-leerlingen daarnaast ook het ouderlijke onderwijsaspiratieniveau ten aanzien van hun kind.
De meeste kenmerken die – naast groepskenmerken, capaciteiten en prestaties – een significante rol bleken te spelen, betroffen leerlingattitudes. De gerichtheid van leerlingen op exacte vakken en moderne talen in leerjaar 1 en hun plezier in het vak wiskunde en (alleen bij VWO-leerlingen) Nederlands in leerjaar 3 waren significante voorspellers voor het gekozen aantal exacte vakken. Eveneens op leerlingniveau speelde het gesignaleerde interactie-effect tussen keuzemotivatie en sekse. Meisjes met een extrinsieke keuzemotivatie ('ik kies deze vakken omdat ze nuttig zijn voor mijn toekomst') waren meer geneigd exact te kiezen dan meisjes met een intrinsieke keuzemotivatie ('ik kies deze vakken omdat ik ze leuk vind/er goed in ben'). Bij jongens was het effect van de keuzemotivatie minder sterk, maar omgekeerd: zij kozen juist minder exact als die keuze extrinsiek gemotiveerd was.

3. Sekse-gerelateerde verschillen in de determinanten en het proces van exacte vakkenkeuze bij VWO-leerlingen (Hoofdstuk 3)

Het onderzoek waarvan in hoofdstuk 3 verslag werd gedaan, startte met dezelfde twee vraagstellingen als in hoofdstuk 2, maar uitsluitend voor zover het de 987 leerlingen in het VWO betrof. De resultaten daarvan vormden vervolgens de basis voor aanvullende analyses die in het tweede deel van hoofdstuk 3 zijn beschreven. In deze analyses werd de proceskant van de exacte vakkenkeuze van de onderzochte VWO-leerlingen nader verkend, via de causale ordening met behulp van padanalysemodellen van de gevonden significante leerling- en oudervariabelen. Omdat uit de resultaten van de eerdere analyses zo duidelijk bleek dat de keuze van exacte vakken voor VWO-meisjes anders verloopt dan voor VWO-jongens, is hieraan speciaal aandacht besteed in dit hoofdstuk. De aanvullende vraagstellingen in hoofdstuk 3 luidden derhalve als volgt:

- *Hoe verlopen de causale relaties tussen de significant gebleken leerling- en gezinskenmerken voor de keuze voor exacte vakken?*
- *Verschilt het causale model ter verklaring van het gekozen aantal exacte vakken tussen jongens en meisjes?*

Het modelleren van het vakkenkeuzeproces van VWO-leerlingen resulteerde in drie causale modellen: één voor alle VWO-leerlingen tezamen en twee seksespecifieke modellen voor de VWO-jongens en VWO-meisjes afzonderlijk De gevonden modellen konden slechts ongeveer een derde deel van de variantie in het aantal gekozen exacte vakken verklaren, daarmee 'presteerden' deze modellen slechter dan het finale meerniveaumodel uit het voorafgaande onderzoek (verklaarde variantie tot 43%) Daar stond echter tegenover dat we door het in kaart brengen van diverse indirecte relaties met het aantal gekozen exact vakken en relaties tussen leerling- en gezinskenmerken onderling, meer inzicht kregen in het vakkenkeuzeproces in het algemeen en de verschillen tussen jongens en meisjes in het bijzonder Onze resultaten bevestigden dat het belangrijk is de vakkenkeuze als een chronologisch proces te zien dat voor jongens en meisjes anders verloopt, onder invloed van verschillende intermedierende variabelen Ten eerste waren enkele kenmerken slechts in een van beide seksespecifieke causale modellen terug te vinden Ten tweede troffen we verschillende seksespecifieke relaties aan En ten derde bleek de volgorde van belangrijkheid van de directe effecten op de keuze van exacte vakken eveneens seksespecifiek te zijn

De meest opmerkelijke conclusie op basis van het gevonden finale model voor alle VWO-leerlingen was dat bijna alle variantie tussen jongens en meisjes in het aantal gekozen exacte vakken (93%) toe te schrijven was aan de directe relatie tussen sekse en het aantal gekozen exacte vakken Met andere woorden alle indirecte effecten tezamen die de potentiele verklaring voor dit fenomeen vormden, hadden maar zeer beperkte invloed op het proces van vakkenkeuze

4. Exact kiezen na de invoering van verplichte profielen in HAVO en VWO (Hoofdstuk 4)

Het onderzoek waarover werd gerapporteerd in hoofdstuk 4, had grote overeenkomsten met het onderzoek uit hoofdstuk 2 Een belangrijk verschil was echter dat het hier ging om leerlingen in HAVO en VWO die verplicht moesten kiezen uit de vier profielen, terwijl de leerlingen in hoofdstuk 2 nog een grote keuzevrijheid hadden De kwantitatieve analyses zijn uitgevoerd op de data van 3513 leerlingen in HAVO en VWO, afkomstig uit het landelijke cohort VOCL'99 In dit cohort zijn leerlingen gevolgd die in schooljaar 1999/2000 in het eerste leerjaar van het voortgezet onderwijs zaten

In het onderzoek is de verhouding onderzocht tussen de persoonlijke capaciteiten van leerlingen in HAVO en VWO enerzijds en hun achtergrondkenmerken anderzijds als verklaring voor de keuze voor een natuurprofiel, waarbij nog onderscheid is gemaakt tussen een profiel natuur & gezondheid en een profiel natuur & techniek De achterliggende onderzoeksvragen luidden als volgt

- *Hoe verhouden zich sinds de invoering van de profielen de bijdragen van sekse en sociaal en etnisch milieu versus prestaties op de keuze van een natuurprofiel door leerlingen in HAVO en VWO?*
- *Welke overige kenmerken op leerling-, gezins- en schoolniveau zijn van invloed op deze keuze?*

Uit de resultaten van de eerste analysefase bleek dat toetsscores in leerjaar 1 en 3 en het schooltype (HAVO of VWO) in leerjaar 5 relatief gezien het meest bijdroegen aan de mate van exactheid van het gekozen profiel. Maar daarnaast waren ook de sekse van de leerling en het ouderlijk opleidingsniveau (c.q. hoogste opleiding in het gezin) nog significant van invloed: jongens en kinderen van hoog opgeleide ouders kozen exacter dan respectievelijk meisjes en kinderen van laag opgeleide ouders.
De tweede analysefase had betrekking op de overige factoren die na de prestaties, sekse en het ouderlijk opleidingsniveau nog een bijdrage leverden aan de mate van exactheid van het profiel. Hieruit kwam een aantal variabelen met een significant effect naar voren die gerelateerd waren aan de attitudes (o.a. waardering voor vakken en docenten, toekomstverwachtingen) en de *aptitudes* (o.a. leerstrategie, rapportcijfers) van de leerling. Andere significante variabelen betroffen de adviezen van de ouders of de school ten aanzien van de profielkeuze.
De onderzochte scholen verschilden significant van elkaar in de mate waarin hun leerlingen een exact profiel kozen. Dat bleek onder meer samen te hangen met de mate waarin scholen de keuze voor een natuurprofiel expliciet hebben gestimuleerd.

5. Verklaringen voor cross-nationale verschillen in deelname aan STEM-onderwijs (Hoofdstuk 5)

In hoofdstuk 5 werd verslag gedaan van een onderzoek naar mogelijke verklaringen voor de cross-nationale verschillen in de deelname aan zogenaamde STEM-studierichtingen in het tertiair onderwijs. De afkorting STEM staat voor Science, Technology, Engineering & Mathematics, in Nederland aangeduid als de (harde) betastudies. Het hoofdstuk startte met een inventarisatie van de verschillen tussen westerse landen in die deelname, zowel in het algemeen als wat het aandeel vrouwen betrof. Uit de verzamelde gegevens bleek dat westerse landen aanzienlijk van elkaar verschillen ten aanzien van het percentage studenten dat kiest voor een betastudierichting in het hoger onderwijs als proportie van het totale aantal studenten, en ook in het aandeel vrouwen daarbinnen. De meest rechtstreekse voorbereiding op een bètastudie in het hoger onderwijs bestaat uit het deelnemen aan de exacte vakken c.q. programma's in de hogere niveaus van het voortgezet onderwijs. Ook in deze deelnamecijfers verschillen de westerse landen vermoedelijk, maar dat viel niet precies aan te tonen door de onvergelijkbaarheid van de secundaire onderwijssystemen.

Daarna zijn in hoofdstuk 5 de resultaten gepresenteerd van een dieptestudie die is uitgevoerd in vier landen: Zweden, Groot-Brittannie, de Verenigde Staten en Nederland. In elk van deze landen zijn mondelinge interviews gehouden met vijf à zes experts. De aldus verzamelde gegevens zijn aangevuld met informatie uit onderzoeksrapporten en andere documentatie. De achterliggende vraagstelling luidde als volgt:

- *Wat verklaart de verschillen tussen westerse landen in de percentages vrouwen en mannen die kiezen voor bètastudierichtingen in het hoger onderwijs, en in welke mate speelt de exacte vakkenkeuze in het hoger voortgezet onderwijs hierbij een rol?*

Het percentage studenten dat een betastudie volgt, berekend ten opzichte van alle studenten in het hoger onderwijs, bleek het hoogst in Zweden, gevolgd door Groot-Brittannie, Nederland en tenslotte de Verenigde Staten. Uit de bevindingen van de dieptestudie hebben we afgeleid dat de kern van de verklaring voor deze volgorde ligt in de toegankelijkheid van, en het aantal instroommomenten in de zogenaamde STEM-pipeline oftewel de bètaroute. Met andere woorden: de mate waarin al vroeg in de schoolloopbaan de juiste keuzes moeten worden gemaakt om uiteindelijk te kunnen instromen in een hogere bètastudie versus de mogelijkheden om aanvankelijke achterstanden op dat terrein later weer te corrigeren. Andere gevonden verklaringen betroffen de mate waarin er sprake is van brede, interdisciplinaire bètastudies versus verkokering en vroege specialisatie, en tenslotte de verhouding tussen de studiekosten enerzijds en het risico op voortijdige studie-uitval anderzijds.

Wat het aandeel vrouwen onder de betastudenten betreft, was de volgorde van de vier landen als volgt: Zweden scoorde wederom het hoogst, gevolgd door de Verenigde Staten, dan Groot-Brittannie en als hekkensluiter Nederland. Deze volgorde hebben we op basis van de resultaten van de dieptestudie voornamelijk verklaard uit kenmerken van de arbeidsmarkt, de maatschappelijke tradities en het overheidsbeleid. Een betastudiekeuze bleek voor vrouwen aantrekkelijker naarmate in een land de vrouwenemancipatie en het *gender*-bewustzijn verder zijn gevorderd en het gebruikelijker c.q. noodzakelijker is dat ook moeders volledig deelnemen aan de arbeidsmarkt. Ofschoon regelingen voor ouder- en zwangerschapsverlof en kinderopvang de deelname van vrouwen aan bètastudies lijken te kunnen beïnvloeden, bleek uit de situatie in de Verenigde Staten dat een relatie hiertussen niet per se noodzakelijk is.
De stelsels van voortgezet onderwijs in de vier bestudeerde landen verschillen van elkaar op diverse aspecten, waaronder de breedte van het onderwijsaanbod en de mate van niveaudifferentiatie en van verplichtingen in de vakkenkeuze. Geen van deze classificaties vertoonde echter een duidelijke relatie met de rangschikking van de vier landen qua algemene en seksespecifieke betastudiekeuze in het hoger onder-

wijs. De structuurverschillen tussen de secundaire onderwijsstelsels leverden derhalve geen duidelijke bijdrage aan de verklaring voor de cross-nationale verschillen in dit opzicht.

6. Onderzoek naar cross-nationale verschillen in gender gaps in het onderwijs (Hoofdstuk 6)

Ook in het kwantitatieve onderzoek dat ten grondslag lag aan hoofdstuk 6 werd een verklaring gezocht voor de cross-nationale verschillen in deelname van vrouwen aan bètastudierichtingen in het hoger onderwijs. In dit hoofdstuk werd dit verschijnsel gerelateerd aan de omvang van de zogenaamde gender gaps in prestaties in het voortgezet onderwijs; dat wil zeggen de relatieve afstand tussen de gemiddelde prestaties van jongens ten opzichte van meisjes. Daarvoor zijn multiniveau analyses uitgevoerd op de data van het internationaal vergelijkende PISA-onderzoek in 2000 en 2001 naar de prestaties van vijftienjarigen op toetsen voor wiskunde, natuurwetenschappen en leesvaardigheid. De analyses hadden betrekking op 224.058 leerlingen op 8.364 scholen voor voortgezet onderwijs in 42 landen.

In het onderzoek is nagegaan of de tussen landen variërende omvang van de gender gaps in prestaties gerelateerd was aan de eveneens variërende deelname van vrouwen aan bètastudies, en welke contextkenmerken samenhingen met de landelijke gender gaps in prestaties. Tevens is onderzocht of de gender gaps in prestaties ook tussen scholen binnen landen varieerden en welke kenmerken hier dan mee samenhingen. De vraagstellingen in hoofdstuk 6 luidden als volgt:

- *In welke mate is er op scholen en in landen sprake van gender gaps in de prestaties voor wiskunde, natuurwetenschappen en leesvaardigheid, en is er op landelijk niveau een samenhang te ontdekken tussen de gender gaps in prestaties in secundair onderwijs en de deelname van vrouwen aan bètastudierichtingen in tertiair onderwijs?*
- *Welke kenmerken van scholen en landen hangen samen met de geobserveerde gender gaps in prestaties?*

Uit de eerste analyses bleek dat meisjes gemiddeld lager presteerden dan jongens op de toetsen voor wiskunde en natuurwetenschappen, terwijl het tegenovergestelde gold voor de leesvaardigheidstoets. Voorts bleek er sprake van een hoge correlatie tussen de omvang van de nationale gender gaps in de prestaties bij wiskunde, natuurwetenschappen en leesvaardigheid. In landen waar de achterstand van de meisjes ten opzichte van de jongens bij wiskunde en natuurwetenschappen kleiner was, was de voorsprong van de meisjes bij lezen groter; in landen waar de leesachterstand van de jongens ten opzichte van de meisjes kleiner was, was de voorsprong van de jongens bij wiskunde en natuurwetenschappen groter.

De analyses lieten ook zien dat de omvang van de gender gaps in prestaties tussen de PISA-landen aanzienlijk varieert. In het onderzoek is die bevinding gerelateerd aan de ondervertegenwoordiging van vrouwen bij bètastudierichtingen in het hoger onderwijs, die eveneens sterk verschilt tussen landen (zie ook hoofdstuk 5). We hebben geconcludeerd dat naarmate in een land de relatieve prestaties van meisjes ten opzichte van jongens in het secundair onderwijs beter zijn, de deelname van vrouwen aan tertiaire bètastudies groter is. Oftewel, een sterke ondervertegenwoordiging van vrouwen in tertiaire bètastudies bleek samen te hangen met een grote prestatie-achterstand in wiskunde en natuurwetenschappen van meisjes ten opzichte van jongens in het secundair onderwijs.

Vervolgens is in het onderzoek gezocht naar verklaringen voor de variatie in de omvang van de gender gaps in prestaties tussen scholen en landen. Daarbij bleek dat meisjes relatief beter presteerden op plattelandsscholen dan op scholen in de grote steden. Met andere woorden, de achterstand van meisjes op jongens bij wiskunde en natuurwetenschappen was kleiner en hun voorsprong bij lezen was groter op scholen op het platteland. Ook bleken de relatieve prestaties van meisjes ten opzichte van jongens gunstiger te zijn naarmate de gemiddelde prestaties van alle leerlingen op een school hoger waren. Een hoger algemeen schoolgemiddelde hing dus samen met een kleinere achterstand van de meisjes bij wiskunde en natuurwetenschappen en een grotere voorsprong van de meisjes bij lezen ten opzichte van de jongens. Hetzelfde gold ook op landelijk niveau, maar dan alleen voor natuurwetenschappen: de achterstand van meisjes bij natuurwetenschappen ten opzichte van jongens was kleiner in landen waar een hoog algemeen gemiddelde op de toets voor natuurwetenschappen werd behaald.
Tenslotte toonden onze analyses aan dat geïntegreerde onderwijssystemen gunstiger zijn voor de relatieve prestaties van meisjes ten opzichte van jongens dan gedifferentieerde onderwijssystemen. Hoe gedifferentieerder het onderwijssysteem, hoe groter de achterstand in prestaties van de meisjes ten opzichte van de jongens bij wiskunde en natuurwetenschappen en hoe kleiner de voorsprong van de meisjes bij leesvaardigheid. Daarnaast bleek de omvang van de gender gap in leesprestaties in een land samen te hangen met de mate waarin vrouwen economisch actief zijn. Meisjes hadden een grotere leesvoorsprong op jongens in landen waar vrouwen economisch actiever waren.

7. Conclusies

Hoofdstuk 2, 3 en 4 van deze dissertatie hadden betrekking op de determinanten van de keuze voor exacte vakken c.q. profielen door een oudere respectievelijk recentere steekproef van leerlingen in HAVO en VWO in Nederland. Uit de onderzoeksresultaten kwam naar voren dat bij deze keuze de prestaties en capaciteiten van de leerlingen een belangrijke rol spelen, en dat is conform de meritocratische gedachte dat de persoonlijke verdiensten van de leerlingen bepalend moeten zijn voor onderwijssucces Maar daarnaast bleek er in beide steekproeven sprake van een eigenstandige significante invloed van sekse en sociaal milieu (i c ouderlijk opleidingsniveau) op hun exacte keuze Dat betekent dat er nog altijd ook een reproducerende component aanwezig is in het onderzochte deel van het Nederlands voortgezet onderwijs De scheidslijnen naar sekse en sociaal milieu leken zelfs wat sterker in de recentere steekproef dan in de oudere ten eerste doordat ook de exacte keuze van de VWO-jongens bleek te worden beinvloed door het ouderlijk opleidingsniveau, en dat was voorheen niet het geval, ten tweede doordat de maximale exacte keuze in de recentere steekproef (een profiel natuur & techniek) door een veel kleiner percentage meisjes werd gekozen dan de maximale exacte keuze in de oudere steekproef (3 exacte vakken) Tegelijkertijd werd in de oudere steekproef een effect van etniciteit aangetroffen dat later was verdwenen, dat duidt er op dat de vakkenkeuze in dat opzicht wel meritocratischer is geworden

In dezelfde hoofdstukken werd ook beschreven welke overige determinanten, na herkomst, sekse en prestaties, van invloed bleken te zijn op de exacte vakken- c q profielkeuze De resultaten met betrekking tot beide steekproeven kwamen in zoverre overeen dat een belangrijk deel van de gevonden kenmerken houdingen van leerlingen betroffen zoals inzet, waardering, toekomstaspiraties en belangstelling In een ruime interpretatie, die echter niet voor iedereen acceptabel is, zijn dat kenmerken die – naast prestaties – ook gelden als persoonlijke verdiensten van leerlingen en dus terecht bepalend zijn voor onderwijssucces In dat geval vormden deze bevindingen een aanvullend bewijs voor het meritocratisch gehalte van het onderwijs Voor beide steekproeven gold echter dat ook kenmerken van de ouders na correctie voor prestaties en capaciteiten nog significant van invloed waren op de exacte keuze van de leerlingen Dergelijke kenmerken behoren zeker niet tot de persoonlijke verdiensten van de leerlingen en konden dus de meritocratische toets niet doorstaan Dat gold ook voor de in Hoofdstuk 3 gesignaleerde verschillen in het vakkenkeuzeproces voor jongens en meisjes waaraan onder meer seksestereotype gedrag van ouders ten grondslag lag
Schoolkenmerken die een significante rol spelen bij de exacte keuze kunnen door hun invloed de reproducerende effecten van sociale en culturele achtergrondkenmerken bevorderen of juist neutraliseren In de analyses die zijn uitgevoerd op de oudere steekproef werd een interactie-effect gevonden dat er op neerkwam dat meisjes op het VWO minder exacte vakken kozen als de rapportvergadering een rol speelde bij de vakkenkeuzeadvisering Dat is een duidelijk voorbeeld van een reproductie-bevorderend schooleffect, waarachter we een sekserolbevestigende bespreking van de mogelijkheden van de meisjes vermoeden In de recentere steekproef werden geen schooleffecten gevonden die samenhingen met een bepaalde maatschappelijke groep of sekse De bevinding dat leerlingen vaker een natuurprofiel kozen als de school dat expliciet stimuleerde, demonstreerde echter wel hoe

scholen er in het algemeen aan kunnen bijdragen dat de capaciteiten van leerlingen beter worden benut

De internationaal vergelijkende onderzoeken in hoofdstuk 5 en 6 toonden aan dat de conclusies ten aanzien van het gebrek aan meritocratische gehalte in het Nederlandse secundair onderwijs ook mogen worden uitgebreid naar het tertiair onderwijs in Nederland en andere Westerse landen Dat bleek uit de overal achterblijvende deelname van vrouwen aan het onderwijs in de exacte vakken en studierichtingen, alsook uit de algemene cross-nationale verschillen in bètastudiekeuze
De verklaringen voor die cross-nationale verschillen, die in deze onderzoeken centraal stonden, kunnen eveneens reproductie-bevorderend of -neutraliserend van aard zijn Een samenleving die wordt gekenmerkt door een gelijke-kansenbeleid, gunstige regelingen voor ouder- en zwangerschapsverlof en kinderopvang, en een volwaardige deelname van vrouwen aan de arbeidsmarkt blijkt een hoger meritocratisch gehalte van het studiekeuzeproces van vrouwen te bewerkstelligen, waar dergelijke kenmerken geheel of gedeeltelijk ontbreken, heeft dat een rolbevestigend en daarmee reproductie-bevorderend effect In algemene zin worden de bèta-capaciteiten van alle leerlingen ook beter benut in landen waar het onderwijssysteem zich kenmerkt door ruimere toegangsmogelijkheden tot de STEM-pipeline (of bètaroute), een gunstige verhouding tussen het *dropout*-risico en de hoogte van de studiekosten, en brede, interdisciplinair opgezette studierichtingen
De verklaring voor de verschillen in deelname van vrouwen aan tertiaire bètastudies op basis van de omvang van de gender gaps in prestaties in het secundair onderwijs, lijkt in lijn met de meritocratische gedachte, omdat hieraan individuele prestaties ten grondslag liggen Daar staat echter tegenover dat het niet de absolute, maar de relatieve prestaties (ten opzichte van het andere geslacht) betreft Bovendien blijken de gender gaps in prestaties samen te hangen met andere contextkenmerken, zoals urbanisatiegraad van de vestigingsgemeente van de school en de mate van differentiatie van het onderwijssysteem, die evenmin te maken hebben met de persoonlijke verdiensten van leerlingen

Op basis van de onderzoeksresultaten die in deze dissertatie zijn beschreven, kan worden geconcludeerd dat zowel het proces van de vakkenkeuze in HAVO en VWO in Nederland als het proces van de studiekeuze in Nederland en in andere Westerse landen niet geheel meritocratisch verloopt Er bestaat nog steeds een duidelijke relatie tussen achtergrondkenmerken van leerlingen en studenten en de mate waarin zij exact kiezen Het gevolg is dat de bestaande maatschappelijke ongelijkheid op het betreffende terrein via het onderwijs ten minste gedeeltelijk wordt gereproduceerd Bovendien wordt daardoor niet optimaal gebruik gemaakt van het aanwezige betatalent in de betrokken landen
Scholen en landen verschillen in de mate waarin ze deze relatie versterken of neutraliseren Beleidsmatig gezien is hier dus zeker nog winst te halen, in die zin dat

de algemene en groepsspecifieke deelname aan het onderwijs in de exacte vakken en studierichtingen kan worden vergroot. Voor scholen lijkt het in dat kader vooral aan te bevelen zich te concentreren op het beïnvloeden van de attitudes van leerlingen en hun ouders; op nationaal en internationaal niveau gaat het ook om bezinning op kenmerken van het onderwijssysteem en om sociale contextkenmerken in de randvoorwaardelijke sfeer.

Diverse zinvolle richtingen voor vervolgonderzoek zijn naar aanleiding van de bevindingen denkbaar. Specifiek binnen Nederland is diepgaander onderzoek nodig naar de motivatie van meisjes die ondanks hoge wiskundeprestaties en rapportcijfers toch niet kiezen voor het profiel natuur & techniek. De vraag is of hier hetzelfde (socialisatie-)mechanisme achter steekt waardoor vrouwelijke werknemers in het algemeen, ondanks vergelijkbare kwaliteiten, nog steeds minder op hoge (management-)functies terecht komen dan hun mannelijke collega's. Het zou relevant zijn na te gaan welke onderwijsstructurele of -curriculaire aanpassingen bij deze meisjes tot een hogere keuze voor het profiel natuur & techniek zouden leiden. Hetzelfde geldt mutatis mutandis natuurlijk ook voor HAVO- en VWO-leerlingen met laag opgeleide ouders, die eveneens geneigd zijn minder vaak een natuurprofiel te kiezen dan op grond van hun prestaties kan worden verwacht. Daarnaast is er grote behoefte aan meer informatie over het verloop van de overgang van Nederlands secundair naar tertiair onderwijs van leerlingen met verschillende profielen. Wat zijn de gevolgen van de startachterstand van leerlingen met een profiel natuur & gezondheid die doorstromen naar een STEM studie, ten opzichte van collega-studenten met een profiel natuur & techniek als achtergrond? Zijn zij door de keuze van het 'te lichte' profiel ernstiger op achterstand gezet dan nodig of zijn toch hun capaciteiten bij aanvang van het profielonderwijs meer voorspellend voor hun succes in het tertiair STEM onderwijs? Al dit soort zaken zou ook in internationaal perspectief onderzocht moeten worden. Vooralsnog stuiten we dan echter op de kwestie van de onvergelijkbaarheid van de onderwijssystemen, met name waar het secundair niveau betreft. Om daarop meer greep te krijgen, zullen nieuwe wegen moeten worden aangeboord.

Curriculum Vitae

Annemarie van Langen (1962) studeerde, na voltooiing van haar gymnasium-Beta in 1980, interdisciplinaire onderwijskunde in Nijmegen met als specialisatie onderwijsbegeleiding en -vernieuwing. Sinds haar afstuderen in 1986 is zij verbonden aan het onderzoeksinstuut ITS van de Radboud Universiteit te Nijmegen, inmiddels als senior-onderzoeker. In de afgelopen jaren heeft zij zich gespecialiseerd in het internationale verschijnsel van de achterblijvende deelname van groepen leerlingen en studenten aan exacte vakken en studierichtingen. Daarnaast houdt ze zich onder meer bezig met onderzoek naar schooleffectiviteit en onderwijskansen voor achterstandsgroepen en is betrokken bij het landelijk cohortonderzoek Primair Onderwijs.

In 1987, the now well-known national campaign entitled "Choose Exact" was launched in the Netherlands. To little avail, however, as frantic efforts are still being made to promote the choice of secondary mathematics and science subjects and tertiary Science, Technology, Engineering and Mathematics (STEM) fields of study. The Netherlands is not alone in its efforts; elsewhere in Europe and the United States, increased participation in such subjects and fields of study is being pursued as well. The lack of interest in the Netherlands, however, is greater than elsewhere.

In this book, Annemarie van Langen reports on a series of studies in which the aforementioned topic stands central. On the basis of data from thousands of pupils in the Dutch upper levels of secondary education (i.e., HAVO and VWO), she offers a number of explanations for the lack of participation in maths and science studies by particular groups of pupils, including girls and the children of lower educated parents in particular. Interviews are also undertaken with experts in Great Britain, the USA, Sweden and the Netherlands in order to find an answer to the question of why more STEM fields of study are pursued in some Western countries than in others. In addition, the association between sex differences in achievement and choice of study is examined with the aid of data from the international PISA study conducted among 15-year-old pupils in more than 42 countries. The results of the studies are of relevance for both researchers and policymakers.

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